Ontario

Air Quality in Ontario

A concise report on the state of air quality in the province of Ontario

1999

Acknowledgments

This report has been prepared by the staff of the Environmental Monitoring and Reporting Branch of the Ontario Ministry of the Environment. The staff of the regional offices of the Operations Division and Laboratory Services Branch of the Environmental Sciences and Standards Division are acknowledged for providing a portion of the air quality data reported herein. Canada's National Air Pollution Surveillance program is also acknowledged for providing air toxics data and quality assurance/quality control of criteria pollutants.

Preface

Clean, healthy air is one of the foundations of the high quality of life enjoyed by the people of Ontario. It is also essential to the Ontario government's commitment to a bold, new 21st century vision of environmental health and safety.

The Air Quality in Ontario 1999 report shows that Ontario's environmental protection efforts are paying off in better overall air quality, continuing a trend that began in the early 1970s. The report also outlines the greatest air protection challenges facing the province.

During 1999, Ontario's air rated good to very good on the Air Quality Index more than 90 per cent of the time. Toronto's air ranked well internationally and finished in second place to Minneapolis/St.Paul for best air quality in the Great Lakes Basin area.

The report documents the following reductions in levels of key pollutants between 1990 and 1999: carbon monoxide (37 per cent), total reduced sulphur compounds (30 per cent), nitrogen oxides (seven per cent) and sulphur dioxide (four per cent).

Volatile organic compounds (VOCs) were detected at trace levels, well below ministry criteria levels, at all monitoring stations. Levels of several chlorinated and aromatic VOCs have decreased since 1996.

As in previous years, ground-level ozone and inhalable particles – the major components of smog – were the pollutants that most often exceeded provincial ambient air quality criteria. The 1999 smog season recorded the highest number of days in the 1990s in which ozone levels exceeded ministry criteria and temperatures rose above 30°C.

The summer of 1999 was characterized by two significant, multi-day smog episodes across southern Ontario – one in mid-July and the other in mid-September. It was the only time the ministry had issued a smog advisory in September since the inception of the Smog Advisory Program in 1993.

Ontario is part of a regional airshed that stretches from the U.S. Midwest into Quebec and the northeastern states. Domestic contributions to air pollution are outweighed by pollutants entering the province from U.S. sources. Prevailing wind patterns make U.S. pollution sources the largest contributors to air pollution in Ontario. This is especially true for smog – on average more than 50 per cent of Ontario's smog is due to pollution from south of the border. The province's successful court interventions supporting the U.S. Environmental Protection Agency's smog requirement will lead to significant benefits for Ontario's air.

Ontario's air pollution initiatives

To combat air pollution, the Ontario government is using a comprehensive and integrated strategy targeting a variety of sectors, including transportation, industry, power utility and residential. Emphasis is being placed on actions that address more than one air-related problem.

For example, during its first year of operation, Drive Clean reduced smog-causing emissions in program areas by an estimated 6.7 per cent and emissions of carbon dioxide, a climate change gas, by an estimated 18,500 tonnes.

Drive Clean was introduced in April 1999 in the Greater Toronto Area and Hamilton. On January 1, 2001, it was expanded to other

urban centres from Peterborough to Windsor, including the Niagara Region. By mid-May 2001, some 2.8 million light-duty vehicles had been tested at 1,492 accredited Drive Clean facilities. Almost 86 per cent of these vehicles passed the test on the first try. Heavy-duty trucks and buses, an important source of microscopic dust particles that can penetrate deep into the lungs and aggravate respiratory problems, are being tested province-wide.

Drive Clean is an important component of the province's Anti-Smog Action Plan, which brings together an unprecedented coalition of sectors to reduce smog-causing emissions by 45 per cent of 1990 levels by 2015. When fully implemented in 2004, Drive Clean is expected to cover five million light-duty vehicles in southern Ontario and 200,000 heavy-duty vehicles across the province.

Progress Since 1999

Ontario is also taking strong action to ensure that other sectors contribute their fair share to the protection of Ontario's air.

As of May 1, 2001, industrial facilities, including iron and steel manufacturers, power generators and petroleum refiners, are subject to a new regulation requiring the tracking and public reporting of 358 airborne pollutants. The regulation makes Ontario the first jurisdiction in the world to require monitoring and public reporting of a full suite of greenhouse gases. A range of other industrial, commercial and municipal facilities in Ontario will also have to track and publicly report on the same list of substances beginning January 1, 2002.

In preparation for the opening of Ontario's competitive electricity market, the government has proposed comprehensive environmental safeguards for the six fossil fuel-fired generating plants owned by Ontario Power Generation. When fully implemented, emission limits for smog and acid rain-causing nitrogen oxides would be reduced by 53 per cent and sulphur dioxide limits would be lowered by 25 per cent. These limits would apply to all other generators in the electricity sector by 2004. The proposals would also require the Lakeview Generating Station to cease burning coal by April 2005.

As part of its commitment to continuous improvement, the Ontario government will constantly review and scrutinize all of its environmental protection efforts, including emissions limits. Information collected through monitoring and reporting will provide information for setting future caps and developing other measures.

Since 1995, the ministry has invested more than $5 million in improving its air monitoring capabilities. In May 2000, Air Quality Ontario was established to give people greater access to timely information about air quality. This information is now being provided for 35 locations in 28 communities in Ontario, including 10 in the Greater Toronto Area.

During the peak smog season (May 1 to September 30) the public has timely access to comprehensive information about current and forecast air quality, putting them in a better position to take appropriate action on bad air days. Air quality reports are provided up to six times daily, seven days a week. Up to three days notice is given when poor air quality is anticipated.

Air Quality Index and Smog Alert information is available at **www.airqualityontario.com**. Smog Advisories are also available by e-mail for subscribers.

The Ontario government constantly seeks ways to strengthen environmental protection in the province. One new direction involves the environment becoming a cross-ministry responsibility. This is already taking place, with the Ministry of the Environment working with several ministries on a long-term plan for reducing emissions from the transportation and industrial sectors.

1999 Report Highlights

- Air quality in Ontario continued to improve over the 10-year period from 1990 to 1999. The provincial averaged levels of carbon monoxide were reduced by 37 per cent, total reduced sulphur compounds by 30 per cent, nitrogen dioxide by seven per cent and sulphur dioxide by four per cent. These improvements in air quality were achieved even as there were increases in Ontario's population, economic activity and vehicular travel during the same period.

- Ground-level ozone and inhalable particles – the major components of smog – once again were the pollutants which most often exceeded provincial ambient air quality criteria.

- The 1999 smog season recorded the highest number of ozone exceedance days and the highest number of "hot" days of the 1990s. However, Ontario continues to record good to very good air quality readings greater than 90 per cent of the time.

- More than 50 per cent of provincial ozone and inhalable particles during widespread pollution episodes are due to long-range transport from neighbouring U.S. states. The U.S. contribution during episodes is expected to be much higher (as much as 90%) in Ontario communities on the eastern shores of Lake Huron and in the southwest near the U.S. border.

- Ontario's real-time fine particle monitoring program has grown by 400 per cent since 1995, to a total of 24 dedicated monitors.

- The summer of 1999 was characterized by two significant multi-day smog episodes across southern Ontario, one in mid-July and the other in mid-September. It was the only time that the ministry issued a smog advisory in September since the inception of the program in 1993.

- Concentrations of volatile organic compounds (VOCs) at ambient sites in Ontario exist at trace levels, well below existing ministry criteria levels.

- On an international basis, Toronto's air quality ranked quite well in 1999 and over a 10-year period (1990-1999). From a regional perspective of the Great Lakes Basin area, Toronto finished in second place for best air quality when compared to other metropolitan cities including Cleveland, Chicago, Detroit and Minneapolis-St.Paul.

Table of Contents

TABLES

FIGURES

Chapter 1

Introduction

Since 1971, the Ontario Ministry of the Environment has been monitoring air quality in Ontario and using this information to:

- inform the public in real time about outdoor air quality;
- provide smog advisories for public health protection;
- assess Ontario's air quality and evaluate trends;
- identify areas where criteria are exceeded, and identify the origins of pollutants;
- provide the basis for air policy development;
- provide quantitative measurements to enable abatement of specific pollutant sources;
- determine the levels of pollutants from U.S. and identify the sources and their effects on Ontario;
- provide air quality researchers with data linking environmental and human health effects to air quality.

Emissions of contaminants into the atmosphere from both human and natural activities, and from the atmospheric interactions of those contaminants, determine air quality. Local air quality is influenced by emissions from motor vehicles and other transportation sources, industrial sources, and meteorological and topographical conditions.

Distant U.S. sources are significant contributors to local air quality for contaminants that undergo long-range transport and transformation, such as ozone, fine particles, trace metals, toxics and the components of acid rain.

Table 1.1 shows the relationship between monitored air pollutants and current air issues. Individual contaminants can have impacts (usually adverse but sometimes beneficial) on a number of air issues at the same time. Such interactions require integration of air issues in order to see the complete picture.

Current Ontario ambient criteria for the common pollutants considered in this report are listed in ***Table 1.2*** along with their potential effects.

This report, 29th in a series, summarizes the state of ambient air quality in Ontario in 1999. It covers measured levels of ozone (O_3), particles and other criteria contaminants such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and total reduced sulphur (TRS) compounds. In addition, the report summarizes the 1999 Air Quality Index (AQI) statistics from the real-time AQI information system, examines regional smog episodes, summarizes the air quality of a select number of volatile organic compounds (VOCs) and provides an international, national and regional perspective on air quality.

Once again, the focus of this year's publication is to report on the state of ambient air quality. The source monitoring statistics, as in the past, will be presented in a separate appendix document, along with the ambient data.

Table 1.1 Linkages Between Air Pollutants and Air Issues

	Smog	Global Warming	Urban Air Quality	Acid Deposition	Health	Aesthetics
Ozone	yes	yes	yes	yes	yes	
Sulphur Dioxide	yes	yes	yes	yes	yes	yes
Carbon Monoxide	yes	yes	yes		yes	
Oxides of Nitrogen	yes	yes	yes	yes	yes	yes
Volatile Organic Compounds	yes	yes	yes		yes	yes
Toxics	yes		yes		yes	
Particles	yes	yes	yes	yes	yes	yes
Total Reduced Sulphur Compounds			yes	yes	yes	

Increased emphasis is now being directed to ozone and inhalable (PM_{10}) and respirable ($PM_{2.5}$) particles, for which scientific evidence suggests significant impacts on health.

Ontario continues to benefit from one of the most comprehensive air monitoring systems in North America. The network is designed to measure air quality at more than 76 continuous air monitoring sites (40 ambient and 36 source stations) across the province and undergoes ongoing maintenance to ensure a high standard of quality control.

Continuous, real-time air quality data are reviewed, assessed and validated constantly. Action is taken immediately to correct anything that may affect the validity of the data. These measures ensure that the ambient air monitoring data are accurate, valid, complete, comparable and representative. As a result, for 1999 the network had 93.2 per cent valid data out of approximately four million data points. With this data, Ontario can make informed decisions about what needs to be done to protect our environment and improve air quality.

Table 1.2 Overview of Criteria Pollutants

Pollutant	Characteristics	Sources	Ontario Criteria	General Health Effects	General Ecological Effects
Ozone (O_3)	A colourless gas. Major component of summer smog.	Ozone is not emitted directly into the atmosphere. It is produced by photochemical action of nitrogen oxides and volatile organic compounds.	1 h average 80 ppb	Irritation of the lungs and difficulty in breathing. Exposure to high concentrations can result in chest tightness, coughing and wheezing. Increased hospital admissions and premature death.	Damage to agricultural crops, ornamentals, forests and natural vegetation.
Inhalable Particles (PM_{10})	Particles of solid or liquid matter that stay suspended in air in the form of dust, mist, aerosols, smoke, fume, soot, etc. Size range less than 10 microns	Industrial processes including combustion, incineration, construction, metal smelting, etc. Also motor vehicle exhaust and road dust. Natural sources such as forest fires, ocean spray and volcanic activity.	24 h average 50 $\mu g/m^3$	Primarily associated with the aggravation of respiratory conditions such as asthma.	Damage to vegetation, deterioration in visibility and contamination of soil.
Respirable Particles ($PM_{2.5}$)	Same as PM_{10} except size range of particles is less than 2.5 microns.	Same as PM10. However, also formed in the atmosphere by the transformation of gaseous precursor emissions such as SO2 and NO_x.	Proposed Canada-Wide Standard 24 h average 30g/m3	Decreased lung function, increased hospital admissions, increased respiratory symptoms and disease, and premature death.	Same as PM_{10}
Total Reduced Sulphur (TRS)	Offensive odours similar to rotten eggs or cabbage.	Industrial sources include steel industry, pulp and paper mills and refineries. Natural sources include swamps and marshes.	1 h average 27 ppb (kraft pulp mill)	Not normally considered a health hazard. They are the primary cause of odours.	
Sulphur Dioxide (SO_2)	Colourless gas with a strong odour similar to burnt matches.	Electric utilities and non-ferrous smelters Also primary metal processing, iron ore smelters, pulp and paper, petroleum refineries, etc.	1 h average 250 ppb 24 h average 100 ppb 1 y average 20 ppb	Breathing discomfort, respiratory illness, aggravation of existing respiratory and cardiovascular disease. People with asthma, chronic lung or heart disease are most sensitive to SO_2.	Leads to acid deposition, which causes lake acidification, corrosion and haze. Damage to tree leaves and crops.
Nitrogen Dioxide (NO_2)	Gas with a pungent and irritating odour.	Automobiles, thermal power plants, incineration, etc.Natural sources include lightning and soil bacteria.	1 h average 200 ppb 24 h average 100 ppb	Increasing sensitivity for people with asthma and bronchitis.	Leads to acid deposition: adverse effect on vegetation.
Carbon Monoxide (CO)	Colourless, odourless, tasteless and poisonous gas.	Major source is transportation sector; i.e., road vehicles, aircraft and railways.	1 h average 30 ppm 8 h average 13 ppm	Impairment of visual perception, work capacity, learning ability and performance of complex tasks.	

Chapter 2

Ozone in Ontario

Ground-level ozone is a gas formed when nitrogen oxides and volatile organic compounds react in the presence of sunlight. Ground-level ozone is the primary component of smog and is different from the ozone in the layer high above the earth that protects us from the sun's harmful ultra-violet (UV) rays. The formation and transport of ozone are strongly dependent on meteorological conditions. Changing weather patterns contribute to short-term and year-to-year differences in ozone concentrations. In Ontario, elevated concentrations of ground-level ozone are generally recorded on hot, sunny days from May to September between noon and early evening.

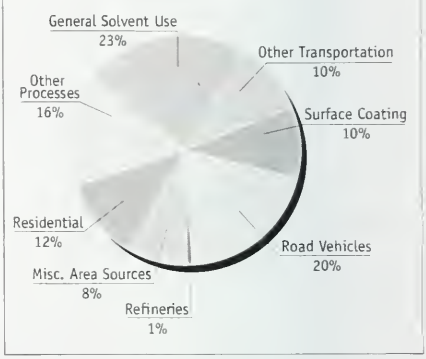
Significant amounts of ozone and ozone-forming compounds are carried into Ontario from the U.S. During periods of widespread elevated ozone, it is estimated that more than 50 per cent of Ontario's ground-level ozone can be attributed to trans-boundary pollution.

Characteristics, sources and effects

Ozone is a colourless, odourless gas at ambient concentrations, and is a major component of smog.

Ground-level ozone is not emitted directly into the atmosphere. It results from chemical reactions between volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of heat and sunlight. ***Figure 2.1*** shows estimates of Ontario's VOC emissions caused by human activity, by sector. Transportation modes account for approximately 30 per cent of VOC emissions. Owing to the large forested area in northern Ontario, biogenic VOC emissions in Ontario are significant – approximately three times those from sources caused by human activity. The sources of NO_x are discussed in the nitrogen dioxide section in Chapter 4.

Figure 2.1
Ontario VOC Emissions by Sectors
(Emissions From Human Activity, 1999 Estimates)



Ozone irritates the respiratory tract and eyes. Exposure to high levels of ozone results in chest tightness, coughing and wheezing. Children active outdoors during the summer when ozone levels are at their highest are most at risk of experiencing such effects. Other groups at risk include individuals with pre-existing respiratory disorders such as asthma and chronic obstructive lung disease. Ozone has been linked to increased hospital admissions and premature deaths. Ozone also causes agricultural crop loss each year in Ontario and noticeable leaf damage in many crops, garden plants and trees.

Figure 2.2

Geographical Distribution of Number of one-hour Ozone Exceedances Across Ontario (1999)

Monitoring results for 1999

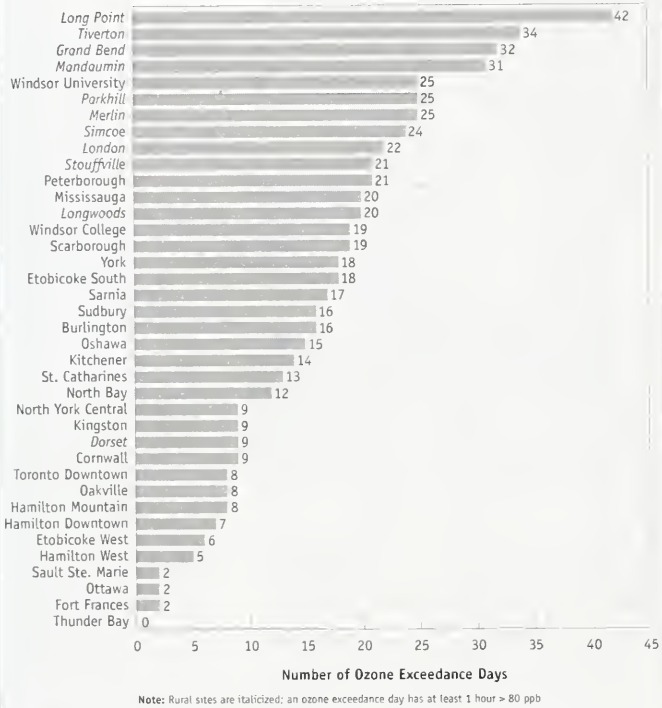
Ground-level ozone was monitored at 39 locations (29 urban and 10 rural sites) during 1999. The highest annual mean (35.6 ppb) was measured at Long Point, a rural site on the northern shore of Lake Erie while the lowest annual mean (18.9 ppb) was measured at Windsor College. Generally, ozone is lower in urban areas because it is removed by reaction with nitric oxides emitted locally by vehicles.

Among urban sites, Sarnia recorded the highest one-hour concentration (145 ppb), London recorded the greatest number of instances (110) of ozone above the one-hour ambient air quality criterion (AAQC) of 80 ppb, and Peterborough, in Eastern Ontario, recorded the highest annual urban mean (31.4 ppb).

At rural sites, Tiverton on the eastern shore of Lake Huron recorded the highest one-hour concentration (139 ppb) and Long Point on

Figure 2.3

Number of Ozone Exceedance Days at Sites Across Ontario (1999)



Note: Rural sites are italicized; an ozone exceedance day has at least 1 hour > 80 ppb

the northern shore of Lake Erie recorded the greatest number of instances (272) of elevated ozone.

The CN Tower ozone monitoring site, located 444 metres above ground level, recorded the highest mean (40.3 ppb), the maximum one-hour (149 ppb) and 24 hour (100.7 ppb) values and the greatest number of instances (368) above the one-hour AAQC.

Ground-level ozone is the pollutant that exceeds its provincial AAQC most often. In 1999, Ontario's one-hour ozone criterion (80 ppb) was exceeded at 38 of 39 monitoring stations on at least one occasion. All 33 ozone monitoring sites in southern Ontario recorded at least one hour of elevated ozone (above 80 ppb) in 1999. At these levels, people with heart and lung problems are at higher risk. Sensitive people may have trouble breathing and their health may be affected if they engage in vigorous exercise.

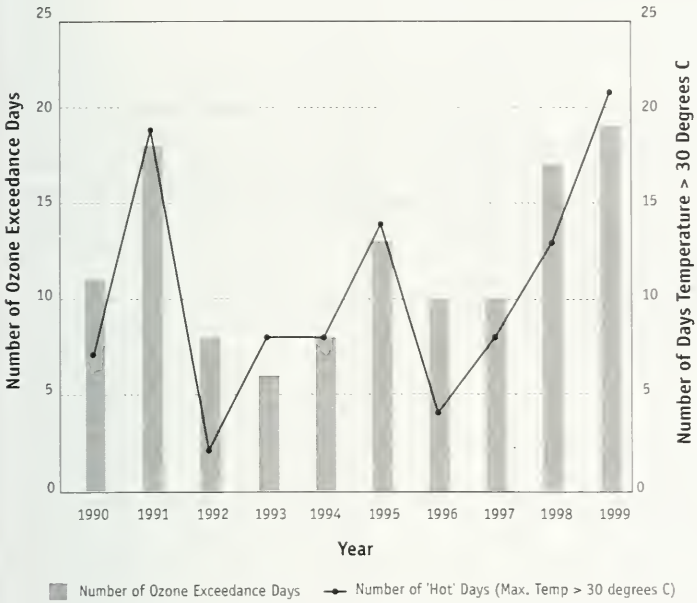
Figure 2.2 shows the geographical distribution of the number of hours of elevated ozone concentrations across Ontario. The higher numbers are found at rural sites in the southwestern part of the province, along both the eastern shore of Lake Huron and the northern shore of Lake Erie. The seriousness of trans-boundary flow is reflected in the relatively higher levels measured there.

Figure 2.3 shows the number of ozone exceedance days (a day with at least one hour above the 80 ppb AAQC) at sites across Ontario. The nine ozone sites recording the highest number of ozone exceedance days in 1999 are located in southwestern Ontario and the top four sites are found in rural areas. Long Point, a rural site on the north shore of Lake Erie, recorded the most exceedance days (42) or about 12 per cent of the days in 1999.

It should be noted that, in general, ozone levels in southern Ontario decrease from southwest to northeast. As mentioned earlier, more than 50 per cent of provincial ozone levels during widespread ozone episodes are due to long-range transport of ozone and its precursors from neighbouring U.S. states. This U.S. contribution during episodes is expected to be much higher, (as much as 90%) in Ontario cities and towns on the northern shores of Lake Erie, eastern shores of Lake Huron, and in extreme southwest, near the U.S. border.

Figure 2.4

10-Year Trend for Ozone Exceedance Days and 'Hot' Days (1990–1999)



Note: 22 ozone sites operated over 10 years; an ozone exceedance day has at least one hour > 80ppb

Trends

Interpretation of the 10-year ambient ozone trends is complicated by meteorology and emission changes from day to day. Year to year, ozone levels are strongly influenced by weather. ***Figure 2.4*** shows the distribution of province-wide ozone exceedance days (at least one hour > 80 ppb) and the number of "hot" days (those with maximum air temperatures greater than 30°C) for 1990 to 1999. Just as the highest number of ozone exceedance days in 1999 is attributable to the weather (highest number of "hot" days), the low numbers in 1992 reflect conditions less conducive to production of ground-level ozone. The 1999 ozone season recorded the highest number of ozone exceedance days and the highest number of "hot" days during the 10-year period.

Overall emissions of VOCs due to human activity show a decreasing trend for the period 1990 to 1995, after which they have remained fairly constant ***(Figure 2.5)***. New vehicle emission standards in the early 1990s and the shift in the consumption of residential fuels from oil and wood to natural gas probably contributed to this decreasing trend. Emissions from forest fires and natural sources are not included in this trend.

The introduction of lower gasoline volatility, which began in the summer of 1989, has resulted in a 2.8 per cent reduction in VOC emissions in 1999. Furthermore, the

Figure 2.5

Trend of Ontario VOC Emissions Estimates (1990–1999)

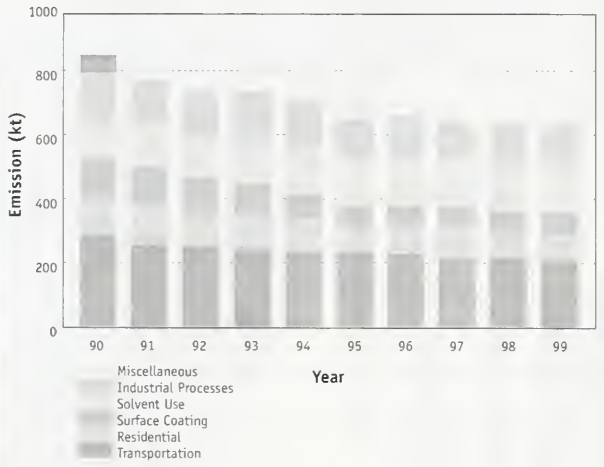
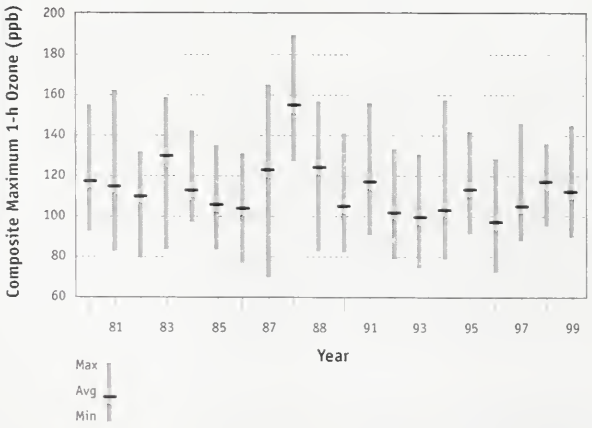


Figure 2.6

Trend of Ozone Composite One-Hour Maximum Concentrations (1980–1999)



Note: 18 ozone sites operated over 20 years

implementation of Ontario's Drive Clean vehicle inspection program in April 1999 has contributed to an additional reduction in VOC emissions. There has been a 19 per cent reduction in VOC emissions over the 1990 to 1999 period.

The effect of changes in VOC emissions, as a precursor of ozone production, is not obvious from the ozone trends discussed below. However, meteorological variability plays a major role in ozone formation as shown by the summers of 1988, 1991 and – more recently – 1998 and 1999.

The trend in the composite one hour maximum ozone concentrations is shown for the 1980 to 1999 period in ***Figure 2.6***. For the entire 20-year period, the composite mean of the maximum one hour concentrations range from approximately 100 to 130 ppb, with the exception of 1988, which had a composite one hour maximum mean of 155 ppb. The composite rural hourly maximum ozone concentration is on average about 10 per cent higher than the corresponding composite urban one hour maximum.

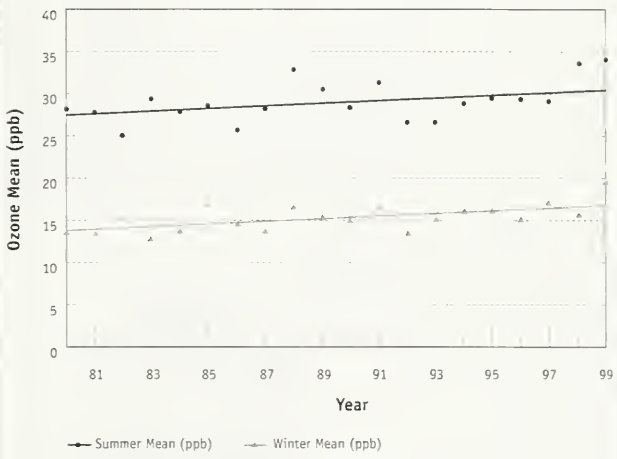
The trend of the ozone seasonal means (summer and winter) for the 18 (12 urban and six rural) long-term ozone sites for the period 1980 to 1999 is shown in ***Figure 2.7***. It shows that there has been an increasing trend in the composite seasonal ozone means during the 20-year period. The summer seasonal ozone mean in 1999 is about 21 per cent higher than the corresponding 1980 summer ozone mean. For the winter period, the 1999 seasonal ozone mean is 43 per cent higher than the corresponding 1980 winter mean. The increase for 1998 to 1999 is one per cent for the summer composite means and 29 per cent for the winter composite means. Comparing the 1999 composite ozone summer mean with the previously highest

record, 1988, shows that for urban sites, the 1999 summer mean is five per cent higher than 1988 while for rural sites it is five per cent lower. Composite ozone winter means during 1999 were higher for both urban (40 per cent higher) and rural (19 per cent higher) than the composite winter means of 1998. Throughout the 1990s, the composite summer and winter ozone means have increased 2.2 and 1.4 per cent per annum, respectively. Similar findings of an increasing trend have been noted in other North American jurisdictions.

The trend of mean annual ozone levels in southern, northern and rural Ontario for 1990 to 1999 is shown in ***Figure 2.8***. It shows that mean annual ozone levels in southern Ontario are consistently about five ppb less than those of northern Ontario and about 13 ppb less than those of rural Ontario. The mean monthly trend of ozone levels in southern versus northern Ontario over the same ten-year period. ***Figure 2.9*** indicates that for the late fall, winter and early spring periods, monthly ozone levels in northern Ontario are approximately twice those of southern Ontario. During the summer months of July and August, the pattern is reversed and southern Ontario records higher monthly means. Possible reasons for the trends noted above are: (a) ozone sites in northern Ontario are far removed from nitrogen oxide emission areas and thus there is less removal of ozone-than in southern urban areas; (b) during the late winter and early spring there is the potential for stratospheric ozone to be injected into the troposphere in northern Ontario; and (c) during the summer months, ozone and its precursors are transported into southern Ontario from the U.S. Midwest.

Figure 2.7

Trend of Seasonal Ozone Means at Sites Across Ontario (1980–1999)



Note: Data from 18 ozone sites; summer (May to Sept.); winter (Dec. to Feb.)

Figure 2.8

Trend for Mean Annual Ozone Levels Southern, Northern and Rural Ontario (1990–1999)

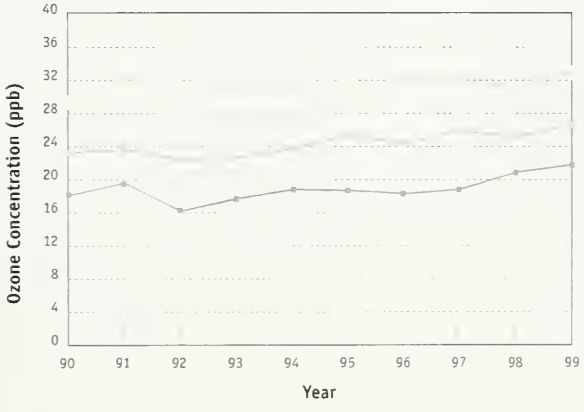
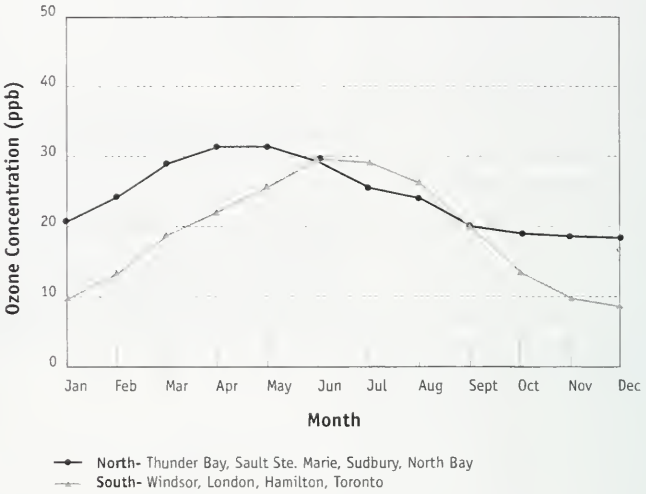


Figure 2.9

Trend for Mean Monthly Ozone Levels South vs North (1990-1999)



Chapter 3

Particles in Ontario's Air

Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. These particles come in a wide range of sizes and originate from many different stationary and mobile sources, as well as from natural sources. PM may be emitted directly from a source or formed in the atmosphere by the transformation of gaseous emissions. This chapter discusses the ambient monitoring results and trends for the 24-hour (sampling every sixth day) inhalable particles (PM_{10}) network, and the real-time continuous inhalable (PM_{10}) and respirable ($PM_{2.5}$) particles network.

Characteristics, sources and effects

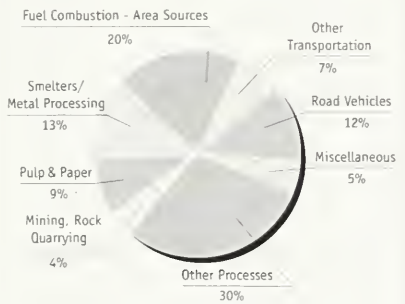
Particles include aerosols, smoke, fumes, dust, fly ash and pollen. Composition varies with place and season. Particles in the atmosphere have been characterized according to size mainly because of the different health effects from particles of different diameters. Particles less than 10 microns and 2.5 microns in diameter are defined as inhalable particles (PM_{10}) and respirable particles ($PM_{2.5}$), respectively. The smaller the particle size, the farther the particle can penetrate into the lungs.

PM_{10} particles are emitted from industrial sources such as fuel combustion, energy production, incineration, construction, mining, metal smelting and processing ***(Figure 3.1)***. In the urban airshed, motor vehicle exhaust, residential wood combustion and road dust are the major sources. Natural sources include wind-blown soil, forest fires, ocean spray and volcanic activity. $PM_{2.5}$ material is primarily formed from chemical reactions in the atmosphere and through combustion.

Figure 3.1

Ontario PM_{10} Emissions by Major Sectors

(Emissions From Area/Point/Mobile Sources, 1995 Estimates)



(1) Emissions from road dusts, construction, agriculture, etc. are not included.

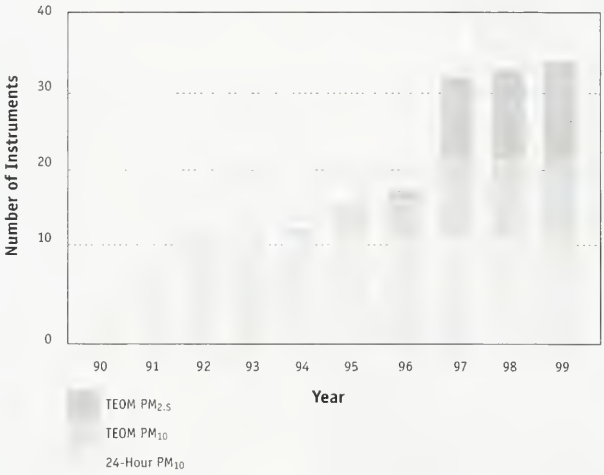
(2) Emissions from open sources from the smelters are not available.

The greatest effect on health is from particles 10 microns or less in diameter, which can aggravate bronchitis, asthma and other respiratory conditions. People with asthma, cardiovascular or lung disease, children, and elderly people are considered to be the most sensitive to the effects of particles. Particles are also responsible for corrosion, soiling, damage to vegetation and reductions in visibility.

In November 1997, as a result of the growing concern for health effects due to fine particles, Ontario introduced an interim

Figure 3.2

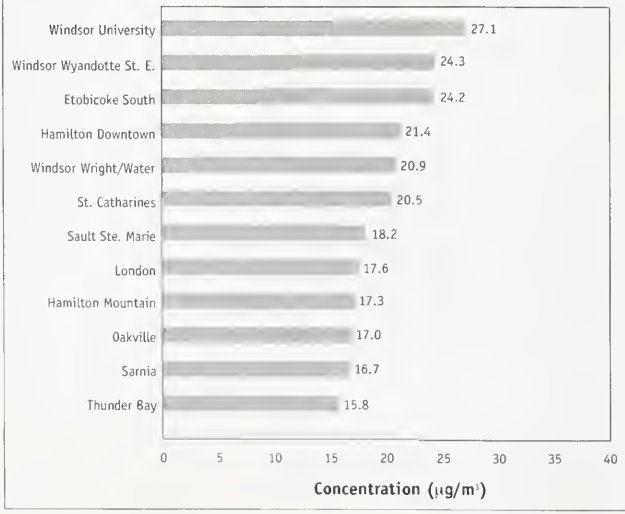
Expansion of Ontario's Ambient PM Monitoring Program (1990–1999)



Note: Metals in PM_{10} and sulphate in PM_{10} are available from 24-Hour PM_{10} samples

Figure 3.3

24-Hour PM_{10} Annual Geometric Means at Ambient Sites Acrosss Ontario (1999)



inhalable particulate (PM_{10}) criterion of 50 µg/m^3 on a 24-hour basis. More recently (June 2000), a draft Canada-Wide Standard (CWS) was signed for the smaller than 2.5 microns ($PM_{2.5}$) fraction, as they pose the greatest potential threat to human health. The proposed CWS for $PM_{2.5}$ uses 30 µg/m^3 on a 24-hour basis. These criteria levels will be used as yardsticks for assessing the data in the following discussion.

Monitoring for 24-hour inhalable particles (PM_{10})

Throughout the 1990s, and particularly from 1996 to 1999, the ministry has increased monitoring for the smaller fraction (less than 10 microns) of the particulate matter due to growing health concerns and its association with trans-boundary pollution. ***Figure 3.2*** shows the growth of Ontario's ambient PM monitoring program during the 1990s.

Twenty-four hour inhalable particles (six-day sampling cycle) are measured by a modified high-volume (hi-vol) sampler outfitted with a size selective inlet to restrict particle size to less than 10 µm. This is the size range of the particle most likely to be inhaled and deposited into the deepest part of the lung (thoracic region). The daily mass of the inhalable particles is computed from the mass of the collected particles and the volume of air sampled. Quartz fibre filters are used as the filter medium for collection. The filters are also analyzed for metals and sulphate composition. These results are presented in the appendix to this report.

In 1999, 24-hour PM_{10} levels were measured at 27 urban locations. Thirteen of the 27 sites monitored for ambient levels and 12 of these will be included in the discussion here. The 13th site, Toronto Downtown, was moved during 1999 and as a result it did not have sufficient data to be included in the analysis. Annual statistics for the remaining 14 sites

located in the vicinity of specific sources can be found in the separate appendix document.

Figure 3.3 shows the distribution of the 24-hour PM_{10} annual geometric means at ambient sites across Ontario. The two sites recording the highest annual means during 1999 were both located in Windsor. The Windsor University Avenue and Windsor Wyandotte Street sites recorded annual means of 27.1 and 24.3 $\mu g/m^3$ respectively, indicating trans-boundary impact. The maximum 24-hour concentration (217 $\mu g/m^3$) was measured at the Wm. Merrifield School site in Sault Ste. Marie, a city with significant local particulate emissions from the iron and steel industry.

Ten of the 12 ambient PM_{10} sites recorded exceedances of the 24-hour interim criterion (50 $\mu g/m^3$) during 1999, as shown in ***Table 3.1.*** The highest percentages were recorded at the two sites in Windsor and ranged from 9.8 per cent at Windsor University Avenue to 13.7 per cent at the Windsor Wyandotte site, once again indicating trans-boundary impact. Oakville and Thunder Bay recorded no exceedances of the provincial interim criterion during 1999.

Trends in 24-hour PM_{10}

The provincial trend in 24-hour PM_{10} levels for six ambient urban locations over the past nine years is shown in ***Figure 3.4.*** No trend is apparent. However, the highest composite geometric mean (22.1 $\mu g/m^3$) was measured in 1994 and the lowest mean (18.4 $\mu g/m^3$) in 1995 and 1997. The 1999 composite mean was 20.0 $\mu g/m^3$.

Real-time $PM_{10}/PM_{2.5}$ monitoring

In June of 1995, the ministry installed a state-of-the-art continuous (inhalable and respirable) monitoring network of five sites across the province. By 1999, this network

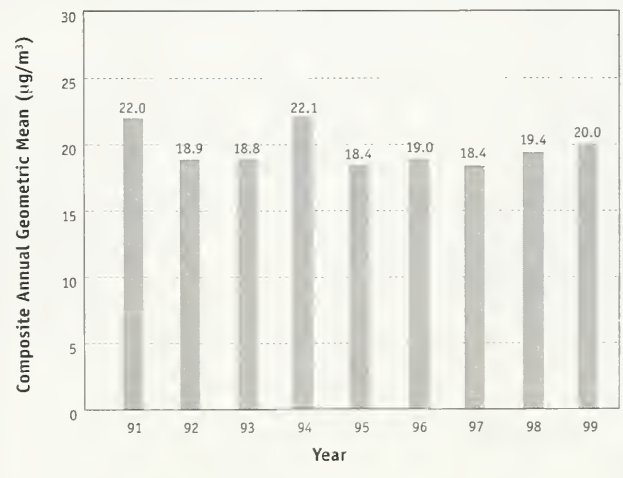
Table 3.1 Percentage of 24-Hour PM_{10} Exceedance Days at Ambient Sites (1999)

Station Number	Station Location	% of Days > 50 $\mu g/m^3$
12513	Windsor Wyandotte Street	13.7
12508	Windsor University Avenue	9.8
15525	London	8.9
29300	Hamilton Downtown	8.8
71368	Sault Ste. Marie	8.2
14564	Sarnia	7.8
12507	Windsor Wright/Water Street	7.0
27308	St. Catharines	6.9
35127	Etobicoke South	4.4
29324	Hamilton Mountain	4.0
44127	Oakville	0.0
63201	Thunder Bay	0.0

Ontario 24-hour interim criterion for PM_{10} is 50 $\mu g/m^3$

Figure 3.4

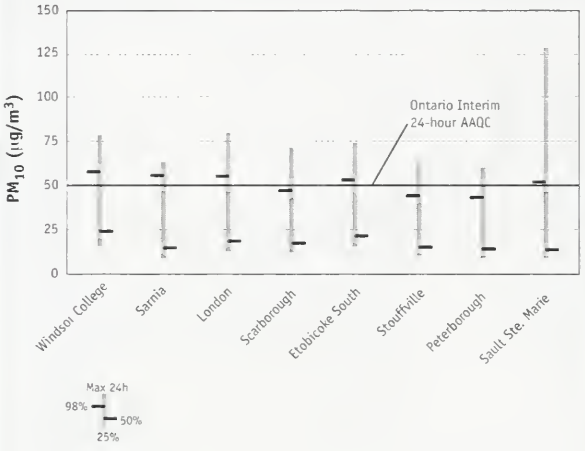
Trend for 24-Hour PM_{10} (1991–1999)



Note: Data for six ambient urban sites

Figure 3.5

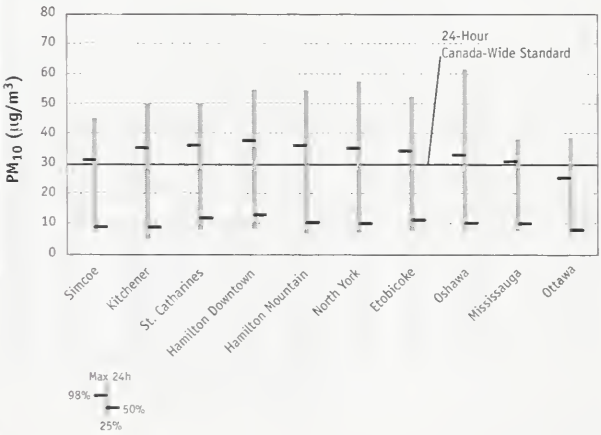
Summary Statistics for 24-Hour PM_{10} as Measured by TEOM (1999)



Note: Data from ambient sites; TEOM – Tapered Element Oscillating Microbalance

Figure 3.6

Summary Statistics for 24-Hour $PM_{2.5}$ as Measured by TEOM (1999)



Note: Data from ambient sites; TEOM – Tapered Element Oscillating Microbalance

has increased in size to a total of 24 sites, 11 PM_{10} and 13 $PM_{2.5}$. Continuous hourly measurements of inhalable and respirable particles are obtained by the Tapered Element Oscillating Microbalance (TEOM) method. The $PM_{10}/PM_{2.5}$ monitoring is intended to allow capture of immediate changes in inhalable particle levels in urban communities, near local industries and in areas affected by trans-boundary sources. Currently, the ministry is investigating the best way to report this information.

Monitoring results for real-time $PM_{10}/PM_{2.5}$

In 1999, monitoring for real-time PM_{10} was conducted at a total of 11 ambient monitoring locations. Eight of the 11 sites recorded sufficient data to be used in this discussion, and their 24-hour statistics for 1999 are shown in ***Figure 3.5***. The annual mean levels for PM_{10} at the eight ambient sites ranged from a low of 16.6 $\mu g/m^3$ in Peterborough to a maximum of 25.9 $\mu g/m^3$ in Windsor. The highest 24-hour average (129.0 $\mu g/m^3$) was recorded at the Wm. Merrifield school site in Sault Ste. Marie. The provincial ambient average for PM_{10} during 1999 was 18.1 $\mu g/m^3$.

In 1999, continuous monitoring for $PM_{2.5}$ was conducted at a total of 13 ambient monitoring locations. Ten of the 13 sites recorded sufficient data to be discussed here and their 24-hour statistics are shown in ***Figure 3.6***. The annual mean levels ranged from a low of 9.8 $\mu g/m^3$ in Ottawa to a maximum of 14.9 $\mu g/m^3$ in Hamilton. The highest 24-hour average (61.6 $\mu g/m^3$) was recorded in Oshawa. The provincial ambient average for $PM_{2.5}$ during 1999 was 12.7 $\mu g/m^3$.

The geographical distribution of the number of PM_{10} exceedance days (24-hour concentration greater than Ontario's interim

of AAQC of 50 µg/m^3) and $PM_{2.5}$ exceedance days (24-hour concentration greater than proposed CWS of 30 µg/m^3) is shown in ***Figure 3.7***. The number of PM_{10} exceedance days ranged from two to 15 in 1999. Fifteen such exceedance days (five per cent of the year) were recorded in Windsor and 14 exceedance days (five per cent of the year) in London. The number of $PM_{2.5}$ exceedance days ranged from three in Ottawa to 23 at the Hamilton downtown site.

During 1999, the PM criteria were exceeded at all PM_{10} and $PM_{2.5}$ monitoring sites in Ontario. Approximately 80 per cent of the fine particle exceedance days occurred during the summer months.

Figure 3.7

Geographical Distribution of PM_{10}/$PM_{2.5}$ Exceedance Days Across Ontario (1999)

Chapter 4

Other Criteria Contaminants

Characteristics, sources and effects of SO_2, NO_2, CO and TRS compounds are discussed in this chapter, as well as their ambient concentrations for 1999 and trends over time. Corresponding annual emission estimate trends are also discussed.

Sulphur Dioxide (SO_2)

Characteristics, sources and effects

SO_2 is a colourless gas that smells like burnt matches. It can be oxidized to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. SO_2 can also be oxidized to form sulphuric acid aerosols. SO_2 is also a precursor to sulphate salts, which are one of the main components of respirable particles in the atmosphere.

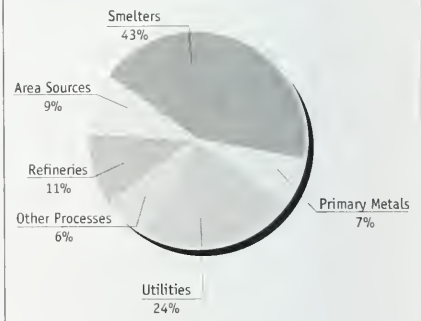
Approximately 67 per cent of the SO_2 emitted in Ontario in 1999 came from smelters and utilities. Other industrial sources include iron and steel mills, petroleum refineries, and pulp and paper mills. Lesser sources include residential, commercial and industrial space heating ***(Figure 4.1)***. The highest concentrations of SO_2 historically have been recorded in the vicinity of large industrial sources.

Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lungs' defences, and worsening respiratory and cardiovascular disease. People with asthma or chronic lung or heart disease are the most sensitive to SO_2. Sulphur dioxide also damages trees and crops. SO_2 and NO_x are the main precursors of acid rain, which contributes to the acidification of lakes and streams, accelerated corrosion of buildings, and reduced visibility. SO_2 also causes formation of microscopic acid aerosols, which have serious health implications and contribute to climate change.

Figure 4.1

Ontario Sulphur Dioxide Emissions by Sectors

(Emissions From Human Activity, 1999 Estimates)



Monitoring results for 1999

Monitoring for SO_2 was performed at 28 ambient locations during 1999. Sarnia recorded both the highest annual mean (11.8 ppb) and the maximum 24-hour concentration (95.8 ppb) during 1999. Science North in Sudbury recorded the highest one-hour concentration (281 ppb). In 1999, the

Science North site in Sudbury was the only ambient site to record an instance above the SO_2 one-hour criterion of 250 ppb. Only one such hour was recorded at ambient sites throughout the entire province during 1999. Furthermore, the 24-hour criterion for SO_2 (100 ppb) was not exceeded during 1999.

Figure 4.2 shows the annual mean SO_2 concentrations at ambient sites across Ontario. Sarnia, Windsor, Etobicoke South and Hamilton recorded the highest annual levels in 1999. The annual levels ranged from 0.4 ppb in Thunder Bay to 11.8 ppb in Sarnia. The annual criterion of 20 ppb for SO_2 was not exceeded during 1999.

Trends

From 1971 to 1999, Ontario's SO_2 emissions decreased 82 per cent, while average SO_2 levels in the province improved by 81 per cent during the same period ***(Figure 4.3)***.

Regulations 346 and 350, control orders on smelting operations and the Countdown Acid Rain program have resulted in these significant decreases over the last two decades. Over the short term, however, SO_2 emissions have shown a slight increasing trend since 1994. This has corresponded with strong economic growth in Ontario over the same period. SO_2 emissions from Ontario Hydro's thermal power plants across the province have increased by about 15 per cent since 1997. This is likely due to the shutdown of eight reactors at the Pickering and Bruce nuclear power plants. However, overall SO_2 emissions in 1999 are down slightly from 1998 because of emission reductions in smelters and other industrial sectors and the introduction of low sulphur in diesel fuel in the transportation sector. Total Ontario SO_2 emissions in 1999 were 609 kilotonnes, down from the 1998 total of 679 kilotonnes and well below the 1994 countdown limit of 885 kilotonnes.

Figure 4.2

SO_2 Annual Mean Concentrations at Ambient Sites Across Ontario (1999)

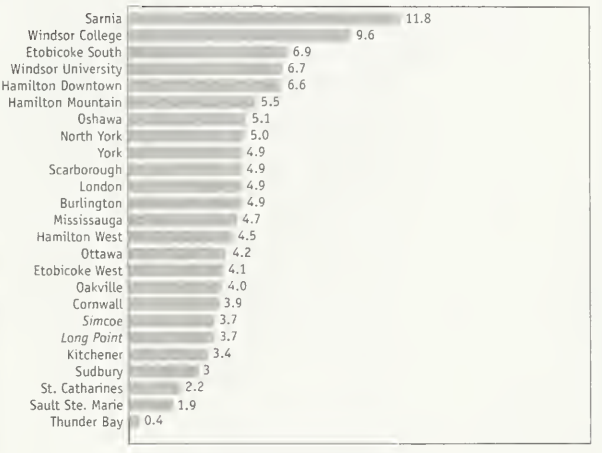
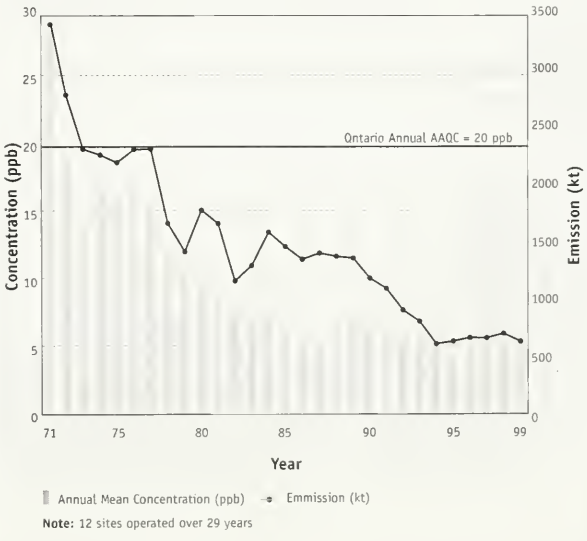


Figure 4.3

Long-Term Trend for Sulphur Dioxide (1971–1999)



Note: 12 sites operated over 29 years

Lambton industry meteorological alert (LIMA)

The Lambton industry meteorological alert is covered by Regulation 350, made under the *Environmental Protection Act*. Application is limited to that part of the County of Lambton bounded by Lake Huron, the St. Clair River, Highway 80, Moore Township and its continuation through that part of Highway 40, and Lambton County Road 27, which includes Sarnia.

The Minister may declare an alert when the 24-hour running average SO_2 concentration at any station in the LIMA system reaches 70 ppb and meteorological forecasts indicate six hours or more of conditions conducive to elevated SO_2 concentrations. The alert is issued at 70 ppb to prevent levels reaching the Ontario 24-hour AAQC for SO_2 (100 ppb).

Two monitoring sites are located in Sarnia (Front Street and Centennial Park) and one in Corunna (River Bend).

Six alerts were issued during 1999. Five of these were based on measurements from the Front Street monitor and one alert was based on measurements from River Bend. The highest 24-hour SO_2 running average (133 ppb) was recorded at Front Street during the LIMA of December 2 to December 4. LIMA alerts called during the past 19 years are shown in ***Figure 4.4***. On average, there have been six alerts called per year since the inception of the program in 1981.

Figure 4.4

Lambton Industry Meteorological Alert (LIMA) Summary (1981–1999)

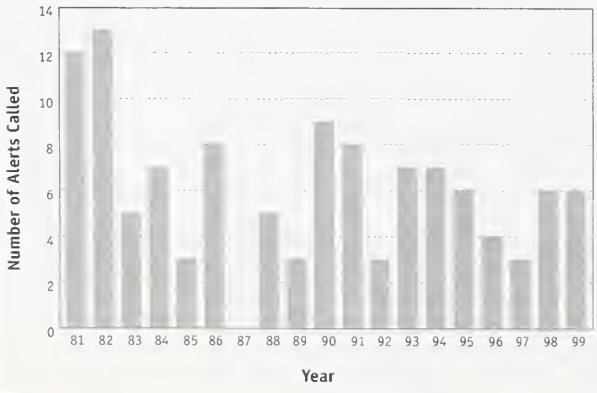
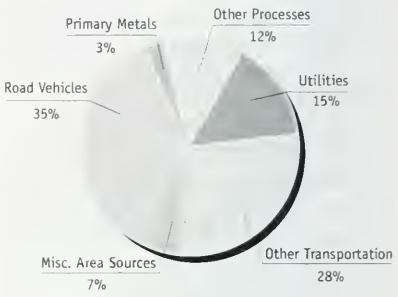


Figure 4.5

Ontario Nitrogen Oxides Emissions by Sectors

(Emissions From Human Activity, 1999 Estimates)



Nitrogen Dioxide (NO_2)

Characteristics, sources and effects

NO_2 is a reddish-brown gas with a pungent and irritating odour. It transforms in the air to form gaseous nitric acid and toxic organic nitrates. NO_2 also plays a major role in atmospheric reactions that produce ground-level ozone, a major component of smog. It is also a precursor to nitrates, which contribute to increased respirable particle levels in the atmosphere ($PM_{2.5}$).

All combustion in air produces oxides of nitrogen (NO_x), of which NO_2 is a major component. Approximately 63 per cent of NO_x comes from the transportation sector in Ontario ***(Figure 4.5)***. A large part of the remaining 37 per cent comes from fossil fuel

power generation, primary metal production and incineration. Natural sources of NO_x include lightning and the aerobic activity of soil bacteria.

NO_2 can irritate the lungs and lower resistance to respiratory infection. People with asthma and bronchitis have increased sensitivity. NO_2 chemically transforms into nitric acid and, when deposited, contributes to lake acidification. Nitric acid can also corrode metals, fade fabrics, degrade rubber, and damage trees and crops.

Monitoring results for 1999

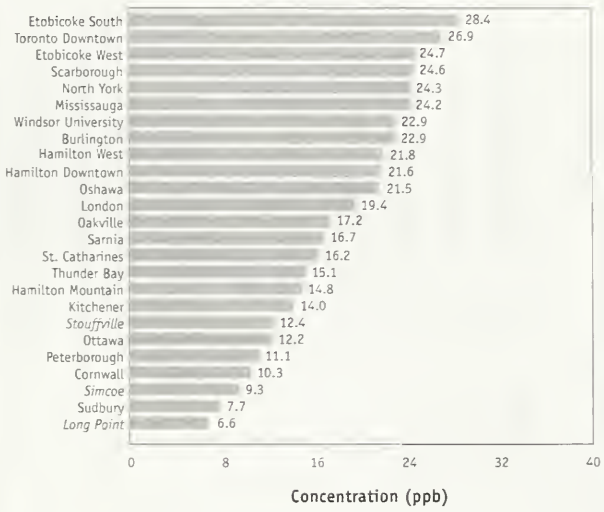
Nitrogen dioxide was monitored at 30 ambient monitoring locations in 1999. Etobicoke South recorded the highest annual mean concentration (28.4 ppb), Hamilton West the maximum one-hour concentration (152 ppb) and Toronto Downtown the maximum 24-hour concentration (68.7 ppb) during 1999. Typically, highest NO_2 annual mean concentrations are recorded in larger urban centres such as Toronto, Mississauga, and Hamilton due to their large vehicle fleets ***(Figure 4.6)***. The one-hour criterion of 200 ppb for NO_2 and the 24-hour limit of 100 ppb were not exceeded during 1999.

Trends

Provincial average ambient NO_2 levels have remained relatively constant throughout the 1990s. Average concentrations in 1999 were about seven per cent lower than the levels recorded in 1990, ***(Figure 4.7)***. Provincial NO_x emissions in 1999 are 17 per cent lower than those of 1990 ***(Figure 4.8)***. This decrease is attributed to reductions in emissions from the industrial and transportation sectors in the early 1990s. The implementation of Ontario's Drive Clean vehicle inspection program in 1999 has resulted in a decrease of NO_x emissions from the light-duty gasoline vehicles sector.

Figure 4.6

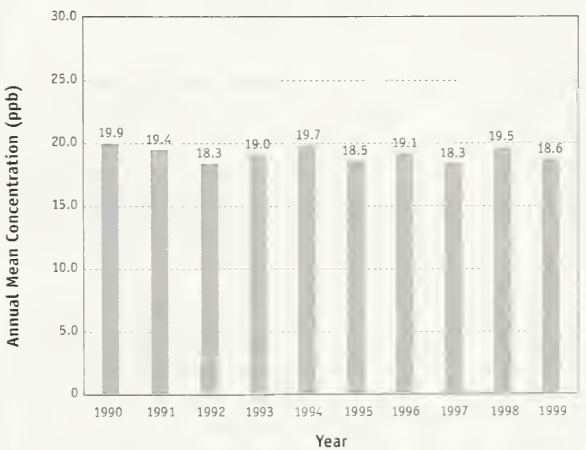
NO_2 Annual Mean Concentrations at Ambient Sites Across Ontario (1999)



Note: Rural sites are italicized

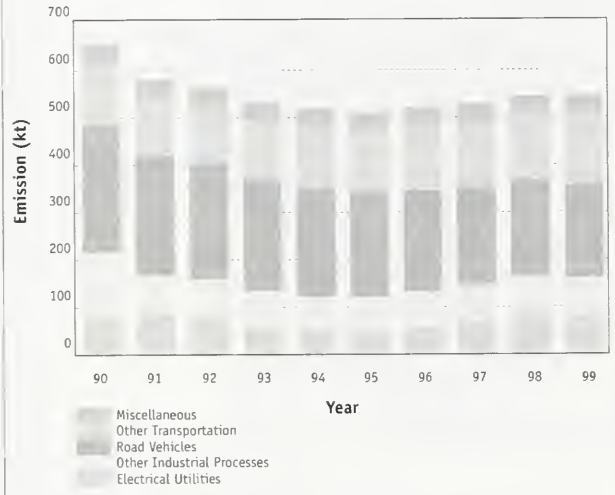
Figure 4.7

10-Year Trend for NO_2 Levels (1990–1999)



Note: 15 ambient sites operated over 10 years

Figure 4.8
Ontario Nitrogen Oxides Emission Trend (1990–1999)



Carbon Monoxide (CO)

Characteristics, sources and effects

CO is a gas produced primarily by incomplete burning of fossil fuels. It is colourless, odourless, tasteless and at high concentrations is poisonous.

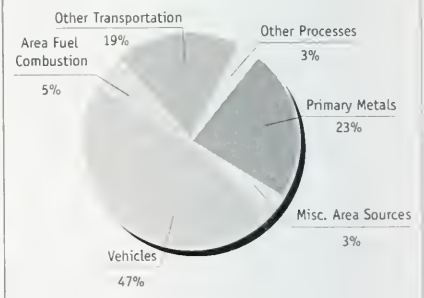
The transportation sector accounts for 66 per cent of all CO emissions from human activity in Ontario ***(Figure 4.9)***. A large part of the remaining CO emissions come from primary metal producers (23 per cent) and from fuel combustion in space heating and industrial processes (five per cent).

CO enters the bloodstream and reduces oxygen delivery to the organs and tissues. People with heart disease are particularly sensitive. Exposure to high levels is linked with the impairment of vision, work capacity, learning ability and performance of difficult tasks.

Monitoring results for 1999

Carbon monoxide was monitored at 22 ambient locations in 1999. The highest annual mean (1.4 parts per million) was recorded at the Etobicoke South site. The highest eight-hour measured value (4.1 ppm) was recorded at York while the highest one-hour concentration (eight ppm) was measured in Mississauga. Highest CO levels are recorded typically in larger urban centres as a result of vehicle emissions ***(Figure 4.10)***. There were no instances of exceeding the one-hour or eight-hour AAQC in 1999. The CO one-hour (30 ppm) and eight-hour (13 ppm) ambient air quality criteria (AAQC) have not been exceeded since 1991.

Figure 4.9
Ontario Carbon Monoxide Emissions by Sectors
(Emissions From Human Activity, 1999 Estimates)



Trends

The trends in provincial averaged one-hour and eight-hour maximum CO concentrations are shown in ***Figure 4.11*** for the period 1990 to 1999. Over this 10-year period, ambient CO concentrations as measured by the composite average of the one- and eight-hour maximums were reduced by 47 and 46 per cent, respectively. The CO composite

annual mean in 1999 is 37 per cent less than the corresponding 1990 composite mean. These reductions in ambient CO levels occurred despite a 16 per cent increase in vehicle-kilometres travelled over the same 10-year period *(Figure 4.12)*.

Provincial CO emissions show a very slight decline in the early 1990s due to the fleet change to newer vehicles with more stringent emission standards *(Figure 4.13)*. The transportation sector accounts for 66 per cent of the provincial total CO emissions. Since 1995, CO emissions have remained constant.

Total Reduced Sulphur (TRS) Compounds

Characteristics, sources and effects

TRS compounds produce an offensive odour similar to rotten eggs or cabbage.

Industrial sources of TRS compounds include the steel industry, pulp and paper mills, refineries and sewage treatment facilities. Natural sources include swamps, bogs and marshes.

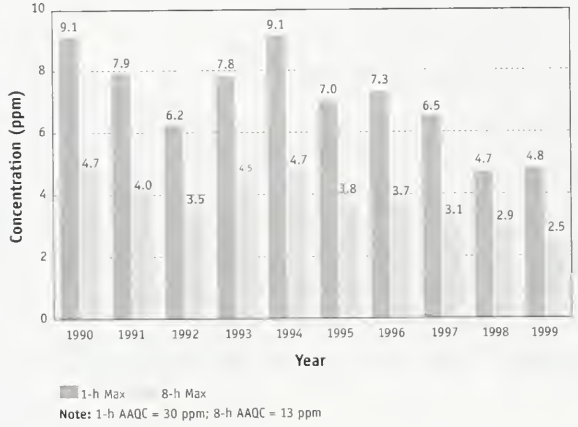
TRS compounds are not normally considered a health hazard except at very high concentrations. They are, however, a primary cause of odours.

Figure 4.10

Geographical Distribution of 1-Hour Maximum CO Concentrations Across Ontario (1999)

Figure 4.11

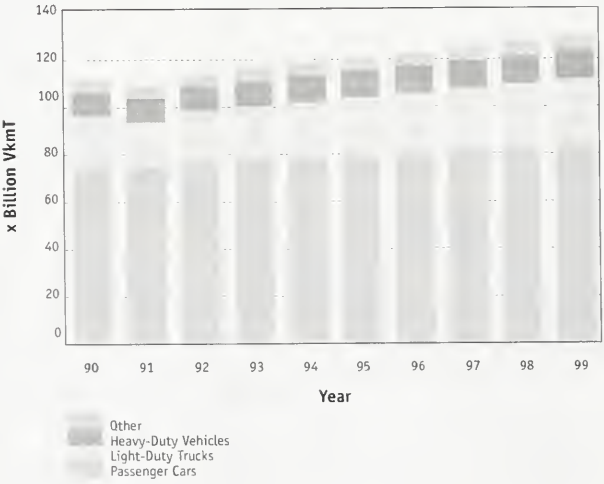
10-Year Trend for CO 1-Hour and 8-Hour Maximums (1990–1999)



Note: 1-h AAQC = 30 ppm; 8-h AAQC = 13 ppm

Figure 4.12

Ontario Vehicle-Kilometres Travelled (1990–1999)



Note: VkmT represents vehicle-kilometres travelled

Monitoring results for 1999

Monitoring for TRS compounds was carried out at 11 ambient locations in 1999. The highest annual mean concentration (1.4 ppb) was recorded in Oakville while the maximum one-hour concentration (59 ppb) was measured in Thunder Bay. The greatest number of hours (19) above the AAQC were recorded at the Windsor College monitor. Elevated TRS levels in Windsor are mainly attributed to trans-boundary impact from Michigan sources.

Trends

The 10-year trend in provincial composite averaged TRS levels at ambient monitoring sites is shown in ***Figure 4.14***. An overall decreasing trend over the 10-year period is evident. Mean averaged ambient TRS levels in 1999 are 30 per cent lower than they were in 1990. This decrease is mainly attributed to abatement and regulatory action taken by the ministry over the years.

Figure 4.13

Ontario Carbon Monoxide Emission Trend (1990–1999)

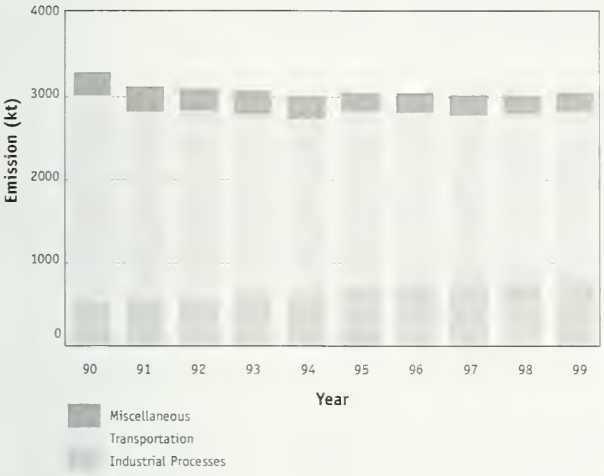
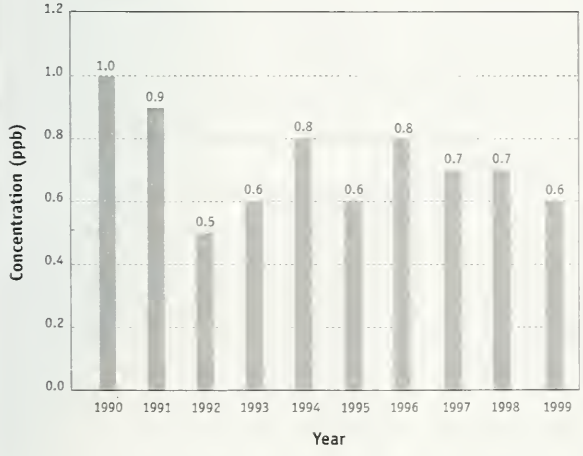


Figure 4.14

10-Year Trend for Annual Mean TRS Levels at Ambient Sites (1990–1999)



Note: 11 ambient sites operated over 10 years

Chapter 5

Air Quality Indices

Air Quality Index (AQI)

The Ministry of the Environment operates an extensive network of air quality monitoring sites across the province. Twenty-seven of these sites in 24 urban centres – including six sites in Toronto – form the basis of the Air Quality Index (AQI) network. The Air Quality Office at the Environmental Monitoring and Reporting Branch continually obtains data for several criterion pollutants from the 27 AQI sites.

This network, in place since the summer of 1988, provides the public with real-time air quality information across the province. The AQI is based on pollutants that have adverse effects on human health and the environment. The pollutants are sulphur dioxide (SO_2), ozone (O_3), nitrogen dioxide (NO_2), total reduced sulphur (TRS) compounds, carbon monoxide (CO) and suspended particles (SP). At the end of each hour, the concentration of each pollutant measured at a particular site is converted into a number that ranges from zero upwards using a common scale or index. The calculated number for each pollutant is called a sub-index.

At a given site the highest sub-index for any given hour becomes the AQI. The lower the index, the better the air quality. The index values, corresponding categories and potential health and environmental effects are shown in ***Table 5.1***.

If the AQI value is below 32, the air quality is considered good. For AQI values in the 32-49 range (moderate category) there may be some adverse effects on very sensitive people. An index value in the 50-99 range (poor category) may have some short term adverse effects on the human or animal populations, or may cause significant damage to vegetation and property. An AQI value of 100 or more (very poor category) may cause adverse effects to a large proportion of those exposed.

Computed air quality indices and air quality forecasts are released to the public and news media at set intervals each day. The public can access the index values by calling the ministry's automatic telephone answering device (ATAD), English recording: 1-800-387-7768 or in Toronto 416-246-0411 and French recording: 1-800-221-8852. The AQI values can also be obtained from the ministry's Web site: **www.airqualityontario.com**.

Air quality forecasts are provided daily based on meteorological conditions and short term pollutant trends in Ontario and bordering U.S. states. These forecasts are provided at the start of AQI report on the ATAD and can also be accessed on the ministry's Web site.

Summary AQI levels (1999)

Table 5.2 shows the frequency distribution of hourly AQI values for the 27 monitoring locations, according to descriptive category and pollutant responsible for AQI above 49. Air quality was most often in the "good to very good" categories at all AQI sites across the province. Based on the cumulative total number of monitored hours (223,652) at the 27 sites, on average, good to very good air quality was reported 93.2 per cent of the time, moderate and poor air quality 6.2 per cent and 0.6 percent of the time, respectively.

Table 5.1 Air Quality Index Pollutants and Their Impact

Index	Category	Carbon Monoxide (CO)	Nitrogen Dioxide (NO_2)	Ozone (O_3)	Sulphur Dioxide (SO_2)	Suspended Particles (SP)	SO_2 + SP (As measured by the API)	Total Reduced Sulphur (TRS)
0-15	Very good	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects
16-31	Good	No known harmful effects	Slight odour	No known harmful effects	Damages some vegetation in combination with ozone	No known harmful effects	No known harmful effects	Slight odour
32-49	Moderate	Blood chemistry changes, but no noticeable impairment	Odour	Respiratory irritation in sensitive people during vigorous exercise; people with heart/lung disorders at some risk; damages very sensitive plants	Damages some vegetation	Some decrease in visibility	Damages vegetation (i.e. tomatoes, white beans due to sulphur dioxide)	Odour
50-99	Poor	Increased symptoms in smokers with heart disease	Air smells and looks brown. Some increase in bronchial reactivity in people with asthma	Sensitive people may experience irritation when breathing and possible lung damage when physically active; people with heart/lung disorders at greater risk; damages some plants	Odourous; increasing vegetation damage	Decreased visibility; soiling evident	Increased symptoms for people with chronic lung disease	Strong odour
100-over	Very poor	Increasing symptoms in non- smokers with heart diseases; blurred vision; some clumsiness	Increasing sensitivity for people with asthma and bronchitis	Serious respiratory effects, even during light physical activity; people with heart/lung disorders at high risk; more vegetation damage	Increasing sensitivity for people with asthma and bronchitis	Increasing sensitivity for people with asthma and bronchitis	Significant effects for people with asthma and bronchitis	Severe odour; some people may experience nausea and headaches

Moderate to very good air quality readings ranged from approximately 100 per cent at Thunder Bay to 98.7 per cent at London. There were a total of 1373 hours (0.6 per cent of hours monitored) of poor air quality recorded at the 27 sites in 1999. Thunder Bay recorded one hour of poor air quality for the entire year and this was due to TRS compounds. Thunder Bay was also the only AQI monitoring site that did not record poor air quality due to ozone. Only one hour of poor AQI due to SO_2 (at Sudbury) and two hours due to suspended particles (at Mississauga) were recorded at the 27 reporting AQI sites during 1999. Poor air quality ranged from 0.0 percent at Thunder Bay to 1.3 percent at London.

Figure 5.1 shows composite pie diagrams of the percentages of very good, good, moderate and poor air quality recorded at sites across

Table 5.2 AQI Statistics (1999)

Station Nfo	City	Valid Hours	No. of Hours AQI in Range					Number of Hours Pollutant Responsible for AQI>49						No of Days at least 1 hr>49
			V-Good 0-15	Good 16-31	Mod 32-49	Poor 50-99	V-Poor 100+	SP	O_3	TRS	SO_2	CO	NO_2	
12008	WINDSOR DTN	8739	5329	2735	569	106	0	0	106	x	0	0	0	25
12016	WINDSOR WEST	8460	5542	2291	547	80	0	0	79	1	0	x	x	19
14064	SARNIA	8760	3875	4209	591	85	0	0	85	0	0	0	0	17
15025	LONDON	8722	4390	3484	738	110	0	0	110	0	0	0	0	22
26060	KITCHENER	8757	4363	3647	670	77	0	0	77	x	0	0	0	14
27067	ST CATHARINES	8760	5271	2840	607	42	0	0	42	x	0	0	0	13
29000	HAMILTON DTN	8610	5602	2534	450	24	0	0	24	0	0	0	0	7
29114	HAMILTON MTN	8760	4632	3455	645	28	0	0	28	0	0	0	0	8
29118	HAMILTON WEST	8710	5308	2958	422	22	0	0	22	0	0	0	0	5
	Average	**8698**	**4924**	**3128**	**582**	**64**	**0**	**0**	**64**	**0**	**0**	**0**	**0**	**14**
31103	TORONTO DTN	7692	5028	2245	393	26	0	x	26	x	0	0	0	8
33003	SCARBOROUGH	8741	5320	2781	563	77	0	x	77	x	0	0	0	19
34020	NORTH YORK	8750	4914	3269	524	43	0	x	43	x	0	0	0	9
35003	ETOBICOKE WEST	5860	3937	1722	187	14	0	x	14	x	0	0	0	6
35033	ETOBICOKE SOUTH	7127	4448	2073	531	75	0	0	75	x	0	0	0	18
36030	YORK	7146	3960	2582	526	78	0	0	78	x	0	0	0	18
44008	BURLINGTON	7353	3657	2933	703	60	0	x	60	x	0	0	0	16
44015	OAKVILLE	7072	3948	2663	427	34	0	0	34	0	0	0	0	8
45025	OSHAWA	8739	4253	3985	449	52	0	x	52	x	0	0	0	15
46110	MISSISSAUGA	8714	4964	3058	593	99	0	2	97	x	0	0	0	20
	Average	**7719**	**4443**	**2731**	**490**	**56**	**0**	**0**	**56**	**0**	**0**	**0**	**0**	**14**
51001	OTTAWA	8637	5067	3291	272	7	0	0	7	x	0	0	0	2
52020	KINGSTON	7940	4690	2750	460	40	0	0	40	x	x	x	x	9
56051	CORNWALL	8702	4274	3880	516	32	0	0	32	0	0	0	0	9
	Average	**8426**	**4677**	**3307**	**416**	**26**	**0**	**0**	**26**	**0**	**0**	**0**	**0**	**7**
62200	FORT FRANCES	8684	3646	4574	422	42	0	0	3	39	x	x	x	16
63200	THUNDER BAY	8480	4349	3951	179	1	0	0	0	1	0	0	0	1
71068	SAULT STE MARIE	8330	4253	3651	418	8	0	0	8	0	0	0	0	2
75010	NORTH BAY	8648	3334	4614	645	55	0	0	55	x	x	x	x	11
77203	SUDBURY	8759	2840	5115	748	56	0	0	55	0	1	0	0	16
	Average	**8580**	**3684**	**4381**	**482**	**32**	**0**	**0**	**24**	**8**	**0**	**0**	**0**	**9**

x - Pollutant not monitored

the province. The pie diagram on the left shows category percentages and that on the right breaks down the poor air quality slice into percentages of pollutants associated with the AQI above 49. Poor air quality at the majority of the AQI sites was due only to ozone. This pollutant accounted for approximately 97 per cent of the number of poor air quality hours recorded during 1999 at the AQI sites. TRS accounted for approximately three per cent of the poor AQI values and was recorded primarily at Fort Frances, a pulp and paper community in northern Ontario. At Fort Frances 39 of its 41 hours of index readings greater than 49 were due to TRS compounds.

Figure 5.1

Air Quality Index Summary (1999)

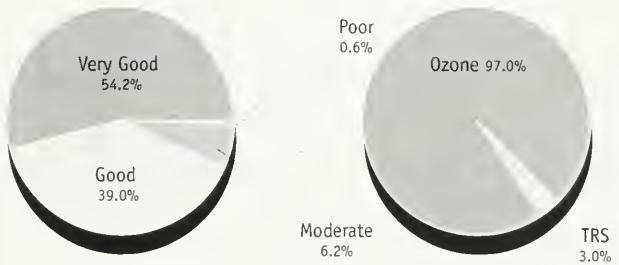
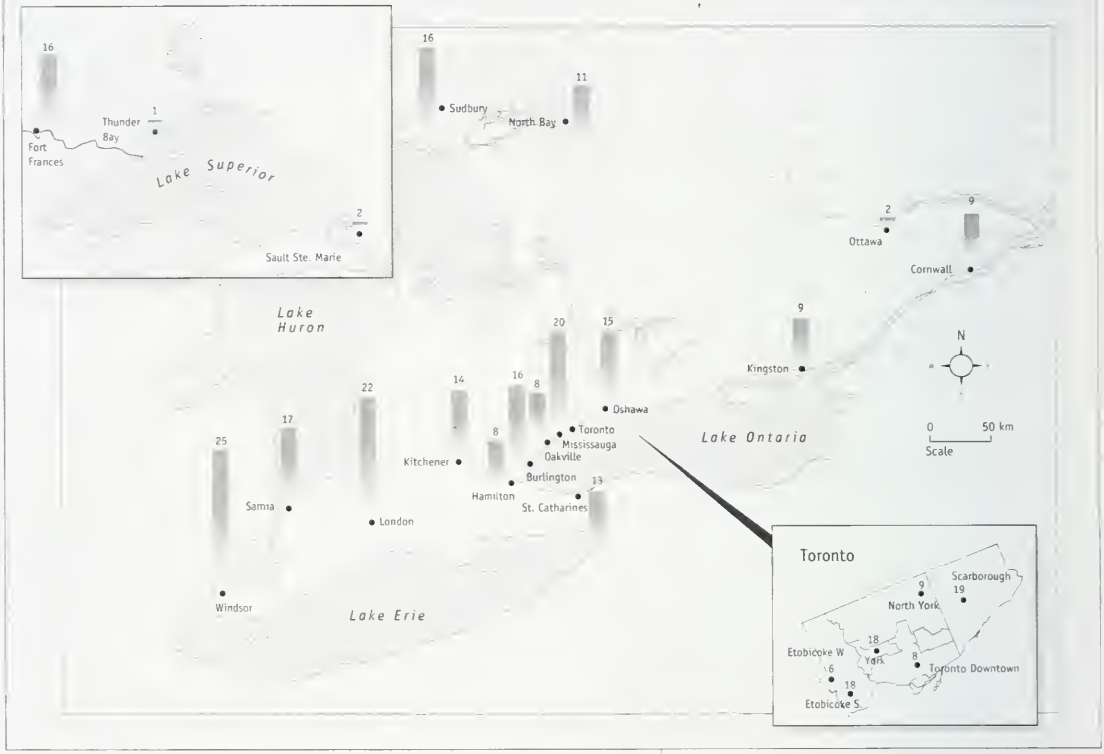


Figure 5.2

Geographical Distribution of the Number of Hours AQI > 49 Across Ontario (1999)

Figure 5.3
Geographical Distribution of the Number of Days AQI > 49 Across Ontario (1999)



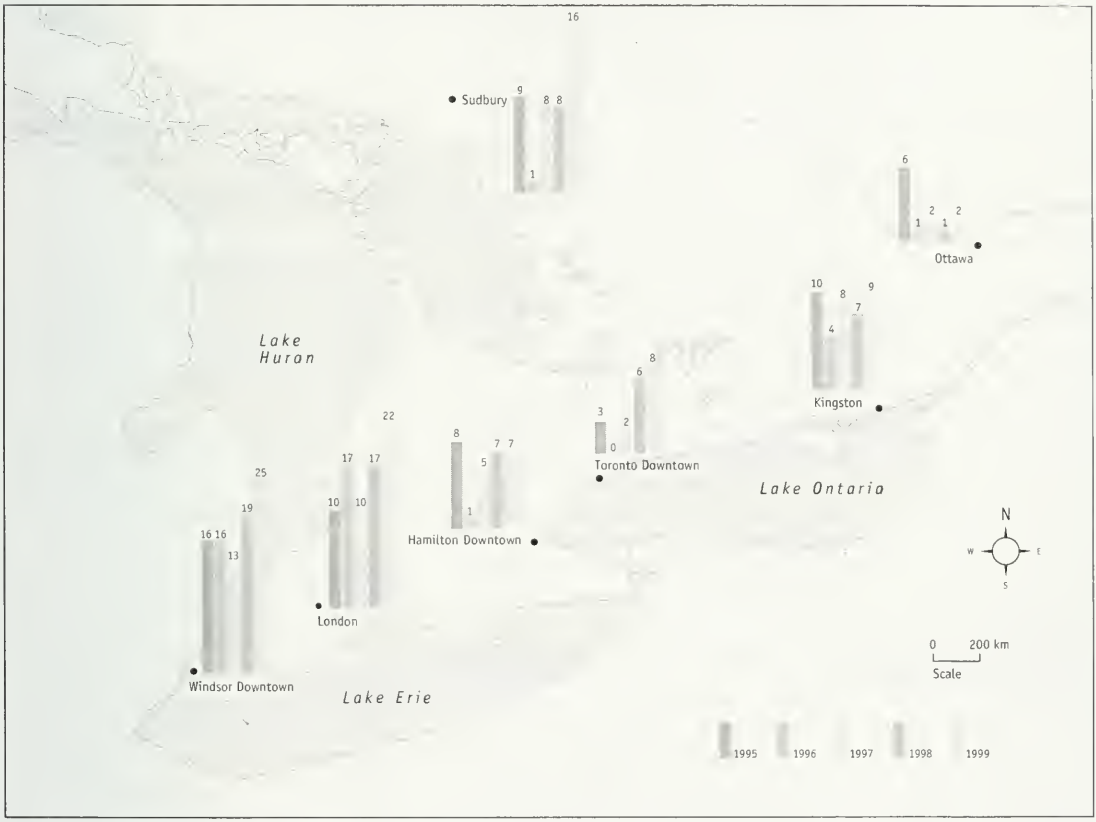
The geographical distribution of the number of hours of AQI > 49 in 1999 is shown in ***Figure 5.2***. The highest number of poor hours were recorded in southern Ontario. No hours of very poor air quality were recorded at the AQI sites during 1999.

Figure 5.3 shows the number of days with at least one hour of air quality in the poor range at AQI sites across the province. The number of days varied from 25 at Windsor University to one at Thunder Bay. Although sites in southwest Ontario recorded the highest number of days with poor air quality, a number of other sites in Ontario also recorded a significant number of such days.

Figure 5.4 shows the number of poor air quality days recorded at selected cities in Ontario for the period 1995 to 1999. The figure shows that the highest number of poor air quality days were recorded in cities in the southwestern portion of the province. These cites are in close proximity to the Ohio Valley region and the U.S. Midwest, major source regions of ozone and its precursors for southern Ontario. Toronto, Sudbury, London and Windsor show an increase in the number of days over the five-year period. The number of poor air quality days ranged from zero in 1996 to eight in 1999 at Toronto Downtown. At Sudbury poor air quality days ranged from one in 1996 to 16 in 1999. Since 1995,

Figure 5.4

Number of Days with at Least One Hour of AQI > 49 at Selected Cities Across Ontario (1995–1999)



Ottawa has recorded the least number of days with poor air quality.

Summary statistics for each region are presented in ***Table 5.3*** showing the percentage time the AQI was in each category and the percentage time each pollutant caused the AQI to be greater than 49. The table shows that in 1999 the southwest region and the GTA had approximately the same percentage of time with air quality in the various categories. The northern region had the lowest percentage of very good air quality but at the same time recorded the highest percentage of air quality in the good category at 51.1 per cent. This is due to the higher number of ozone values in the good category during the winter and spring seasons in northern Ontario.

Regional AQI trends (1995-1999)

A five-year trend (1995-1999) for the average number of days that the AQI was greater than 49 (in the poor category) by region is shown

Table 5.3 Air Quality Index Summary Statistics by Regions (1999)

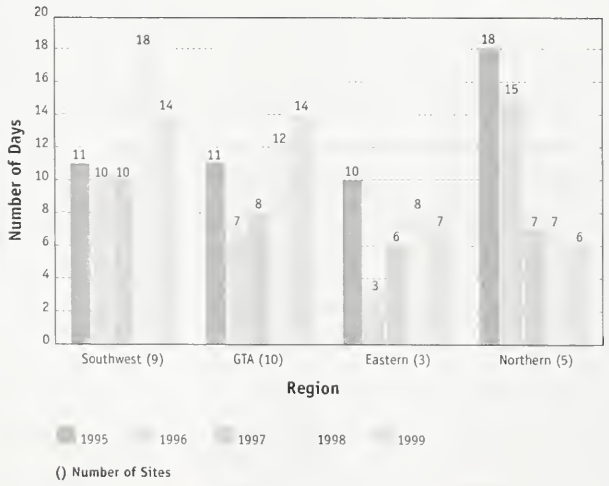
Regions	% of time AQI in Range				% Time Pollutant Responsible for AQI > 49			
	V-Good	Good	Moderate	Poor	SP	O_3	TRS	SO_2
Southwest	56.6	36.0	6.7	0.7	0.0	100.0	0.0	0.0
GTA/Central	56.7	36.1	6.5	0.7	1.0	99.0	0.0	0.0
Eastern	55.5	39.3	4.9	0.3	0.0	100.0	0.0	0.0
Northern	42.9	51.1	5.6	0.4	0.0	75.0	25.0	0.0

API, CO and NO_2 are also monitored at sites but did not cause the AQI to be in the poor category during 1999.

in ***Figure 5.5***. The average number of days with at least one hour greater than 49 showed an increasing trend since 1995 in the southwest and GTA. The GTA was the only region that had an increase in the number of poor air quality days recorded in 1999 over that of 1998. This was due to a large increase in the number of AQI values in the poor category during 1999. The average number of hours of poor air quality due to ozone in the GTA was 55 per cent higher than in 1998 (57 hours on average per site in 1999 compared to 38 in 1998). The northern region shows a continuous decrease in AQI days greater than 49 during this period. In Northern Ontario there has been a significant reduction of TRS levels at Fort Frances. In the Eastern Region the average number of poor days decreased from 1995 to 1999, with the fewest number of poor days (three) recorded in 1996.

Figure 5.5

Trend in the Number of Days with AQI > 49 for Various Regions of Ontario (1995–1999)



Air Pollution Index (API)

The air pollution index continues to be the basis of an alert and control system to warn of deteriorating air quality and is derived from 24-hour running averages of sulphur dioxide and suspended particles as defined by a measurement known as the coefficient of haze (COH). Research studies have linked respiratory illness to high concentrations of sulphur dioxide and particulate matter.

Ontario's *Environmental Protection Act* authorizes the Minister of the Environment to order any point source not essential to public health or safety to curtail or cease its operation when air pollution levels which may be injurious to health occur.

The API is computed each hour based on the previous 24 hourly values for SO_2 and SP. If the index reaches 32 and the duty meteorologist predicts a continuation of adverse atmospheric conditions for at least

six hours, an Air Pollution Advisory may be issued. Owners of significant sources of pollution are advised to prepare for possible curtailment of operation.

The First Alert Level is reached if the index reaches 50. If at least six hours of adverse atmospheric conditions are forecast, owners of major sources may be ordered to curtail operations. A second alert is issued at an API of 75 and further curtailment may be ordered.

The Air Pollution Episode Level occurs at an API of 100 and owners of all sources not essential to public safety may be ordered to cease operations if atmospheric conditions are not expected to improve for at least six hours.

API summary (1995-1999)

In 1995 the Advisory level of 32 was exceeded at three sites, Hamilton Downtown on three occasions and Hamilton West and Etobicoke South on one occasion. Hamilton Downtown recorded the highest API value of 39 in 1995. In 1996, Hamilton Downtown was the only API site that reached the advisory level of 32 and this was reached on only one occasion. Windsor West was the only site in 1997 that recorded an API above the Advisory threshold of 32, recording an API of 34 on one occasion.

During 1998 and 1999 the Advisory level of 32 was not reached at any of the API sites.

Meteorological impact on air quality

Air quality is affected by meteorological conditions through the transport and dispersal of pollutants. Pollutants in the air may be subject to photochemical reactions or removal by precipitation washout or gravitational settling out of the atmosphere. For the summer period, May 1 to September 30, the significant weather factors that affect air pollutant concentrations and smog episodes are:

- wind speed and direction
- temperature (maximum daily temperature, number of hot days, and mean daily temperature)
- cloudiness (which affects the amount of sunshine)
- rainfall amount
- stability of the atmosphere

Wind transports pollutants away from their sources and disperses them in the air. Higher wind speeds and greater numbers of windy days result in better dispersion of pollutants. Depending on direction, the wind may also transport pollutants generated outside of Ontario into the province. Temperature of the air affects stability of the atmosphere, the rates of chemical reactions of some pollutants and cloudiness, which influences the amount of sunshine and rainfall. Temperature also affects the amount of fuel used for heating and cooling, which in turn releases air pollutants.

The amount of bright sunshine affects the rates of photochemical reactions that generate smog. Rainfall washes out and removes some pollutants from the atmosphere. Stable atmospheric conditions lead to inversions that tend to restrict vertical mixing of air, causing pollutants to become trapped in a shallow layer where pollutant concentrations may increase to unhealthy levels.

A particular weather pattern can provide all or most of the conditions most likely to favour smog formation and the development of smog episodes. Slow-moving high-pressure patterns tend to support the conditions of high temperatures, low wind speeds, stable lower atmosphere, strong thermal inversions, minimum cloud development, abundant sunshine and minimum precipitation.

Temperature summary (1999)

During 1999, each of the months from May to September except August were warmer than normal. Both the mean monthly temperatures and maximum monthly temperatures were generally several degrees Celsius (°C) above normal. For example, in Toronto in July, the mean daily maximum temperature was 30°C, while the normal for that month is 26.8°C, and the mean daily temperature was 24.3°C while the normal is 20.5°C. In Ottawa, in May, the mean daily maximum temperature was 22.9°C while the normal is 18.6°C, and the mean daily temperature was 16.3°C while the normal is 12.8°C. Temperatures in August were very close to normal. For example, London's mean daily maximum temperature was 24.8°C while the normal is 25.2°C, and the mean daily temperature was 19°C, while the normal is 19.3°C. ***Table 5.4*** lists the deviations from the normal of monthly maximum and monthly mean temperatures for selected Ontario locations for the months of May through September 1999. For 1999, the entire Great Lakes-St. Lawrence region experienced the warmest spring and summer of the previous 10 years and the sixth warmest spring and summer of the previous 50 years. (Environment Canada climate data available at http://www.msc-smc.ec.gc.ca/ccrm/bulletin/).

The number of hot days per year (where the maximum temperature is greater than or equal to 30°C) in Ontario was greater in 1999 than in each year of the previous decade. For example, London had 20 hot days in 1999, 12 in 1998, and 16 in 1991. Toronto had 24 hot days in 1999, 20 in 1998, and 21 in 1991. Kingston had seven hot days in 1999, 6 in 1995, and three in 1991. The numbers of hot days for the years 1991 to 1999, for selected locations in Ontario, are listed in ***Table 5.5***.

Precipitation summary (May to September 1999)

Precipitation totals were generally less than normal in southern Ontario and greater than normal in northern Ontario during the period from May to September 1999. For example, in Hamilton, total rainfall for the period May to September was 331.9 mm, while the normal for this period is 398.3 mm. In Sudbury, total rainfall for the period May to September was 534.9 mm, while the normal for this period is 415.1 mm. ***Figures 5.6a*** and ***5.6b*** show the deviation in monthly rainfall, as a

Table 5.4 Deviation in Maximum and Mean Monthly Air Temperatures (°C) from Normal for Locations in Ontario (May-September 1999)

Station	May		June		July		August		September	
	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean
Hamilton	2.3	1.9	1.9	1.8	3.2	2.4	-0.8	-0.8	2.1	1.4
Kingston	4.9	3.9	4.3	3.7	2.9	2.8	0.1	0.3	2.6	2.5
London	2.9	2.5	1.2	1.8	2.6	2.6	-0.4	-0.3	2.8	1.7
Ottawa	4.3	3.5	2.9	2.7	1.8	1.7	0.0	0.2	3.2	3.2
Sudbury	3.8	3.3	2.2	2.2	0.9	1.3	-0.3	-0.4	3.2	2.6
Thunder Bay	1.1	1.4	1.4	1.4	1.3	1.4	0.2	-0.4	0.9	0.5
Toronto	2.8	3.2	2.1	3.0	3.2	3.8	-0.6	0.8	2.4	2.7
Windsor	2.3	2.3	1.6	2.0	3.0	2.9	-0.4	1.5	2.5	2.7

Table 5.5 Number of Hot Days per Year at Selected Locations Across Ontario (1991-1999)

Location	1991	1992	1993	1994	1995	1996	1997	1998	1999
Hamilton	15	1	11	5	17	3	7	15	26
Kingston	3	0	2	3	6	1	0	1	7
London	16	0	6	7	13	2	4	12	20
Ottawa	22	3	8	7	18	6	17	12	22
Sudbury	13	0	4	5	9	1	7	3	8
Thunder Bay	11	2	2	0	0	0	0	0	0
Toronto	21	2	14	9	16	1	14	20	24
Windsor	40	2	19	16	24	17	11	37	37

percent of the normal, for selected cities in northern and southern Ontario during the period from May to September 1999.

Winds and ozone transport

Wind direction significantly affects smog episodes in southern Ontario during the summer.

Southwest winds into Ontario can transport significant levels of pollutants. An ozone pollution rose diagram is shown in ***Figure 5.7*** for Windsor for the summer period of 1999. The diagram shows the directions from which the winds were blowing when ozone concentrations were greater than 50 ppb. It can be seen that the greatest occurrence of ozone episodes (with concentrations greater than 80 ppb) also coincided with winds coming from the south.

Meteorological summary

In 1999, for the population centres of Ontario, the "smog season" months from May to September were generally warmer than normal and thus were more likely to experience the conditions that lead to increased smog formation. Furthermore, with a greater number of hot days than normal, Ontario experienced conditions which were more conducive to the production and transport of ozone into Ontario. With less precipitation than normal in southern Ontario, there was less removal of pollutants from the atmosphere, leaving higher concentrations of pollutants remaining in the atmosphere for a longer period of time.

Figure 5.6a

Monthly Rainfall Deviation from Normal for Southern Ontario (May–September 1999)

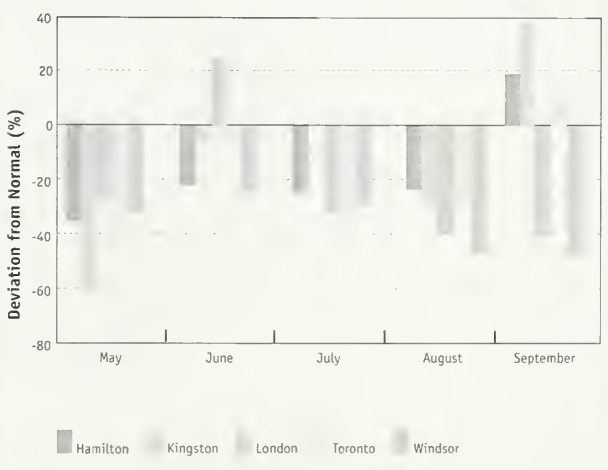


Figure 5.6b

Monthly Rainfall Deviation from Normal for Northern Ontario (May–September 1999)

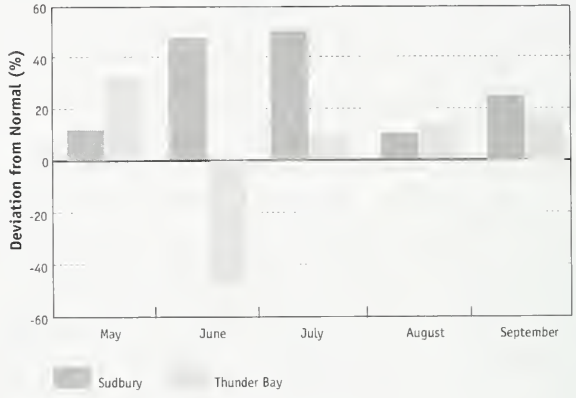
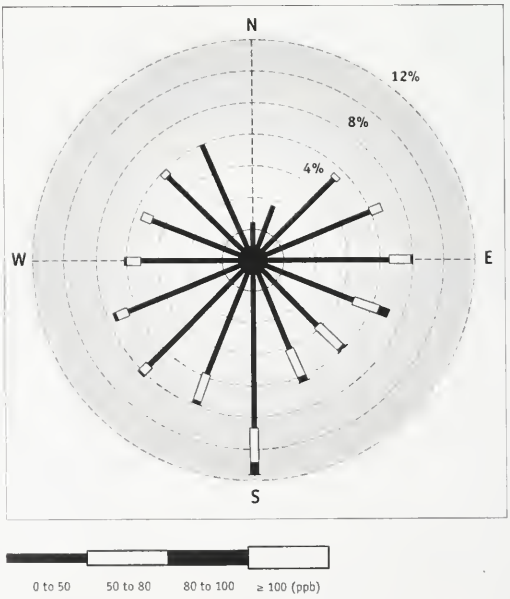


Figure 5.7

Ozone Pollution Rose for Windsor for Ozone Concentrations above 50 ppb (May 1 to September 30, 1999)



Chapter 6

Regional Smog Episodes

The generation, build-up and dissipation of smog over eastern North America is strongly influenced by synoptic-scale weather systems. In particular, pollutants associated with various air issues (e.g., acid species, ground-level ozone and its precursors, fine particles and persistent organic pollutants) are often transported by large-scale weather systems up to thousands of kilometres from their point of origin before being deposited or impacting on receptors. Thus, long-range transport and trans-boundary flow of air pollutants have a significant role in air quality considerations on a regional scale.

For southern Ontario, this is particularly evident for ozone during late spring and summer. Elevated ozone is a primary component of photochemical smog where the precursors – nitrogen oxides and hydrocarbons (volatile organic compounds) – react in the air in the presence of sunlight. The ozone tends to be formed downwind of precursor sources and is thus capable of travelling long distances through the atmosphere. As a result, ozone is often a manifestation of long-range transport and trans-boundary flow of air pollution (***Figure 6.1***).

Episodes of elevated ozone at ground level usually occur between May and September, and are associated with high pressure weather systems that typically move out of Central Canada into the U.S. midwest or the Great Lakes area and then eastward to the Atlantic coast. The frequency of these episodes varies from year to year and depends on large-scale weather patterns and meteorological factors.

Episodes in southern Ontario are often a part of a regional condition that prevails over much of northeastern North America. For southern Ontario, it is a significant trans-boundary problem because elevated pollution levels are often due to weather patterns that affect the lower Great Lakes Region, resulting in the long-range transport of ozone and its precursors from neighbouring U.S. industrial states. Ontario often shares a common airshed with several neighbouring states, hence emissions in one source area can affect air quality in the whole airshed.

Figure 6.2 illustrates a generalized synoptic weather pattern over southern Ontario during high smog potential conditions. The back portion of a slow-moving high-pressure system generally has winds with a southerly component that has travelled over major precursor source areas located in the midwest and eastern United States.

As the high pressure moves west to east, precursors are emitted into the front of the system and circulate to the rear over a period of two to six days, depending on the wind speed. This results in the accumulation of a number of pollutants (both primary and secondary species) in the air mass. Thus, south to southwesterly flow on the rear side of a high-pressure cell provides favourable conditions for transport of pollution and is

Figure 6.1

Transboundary Air Flow into Ontario

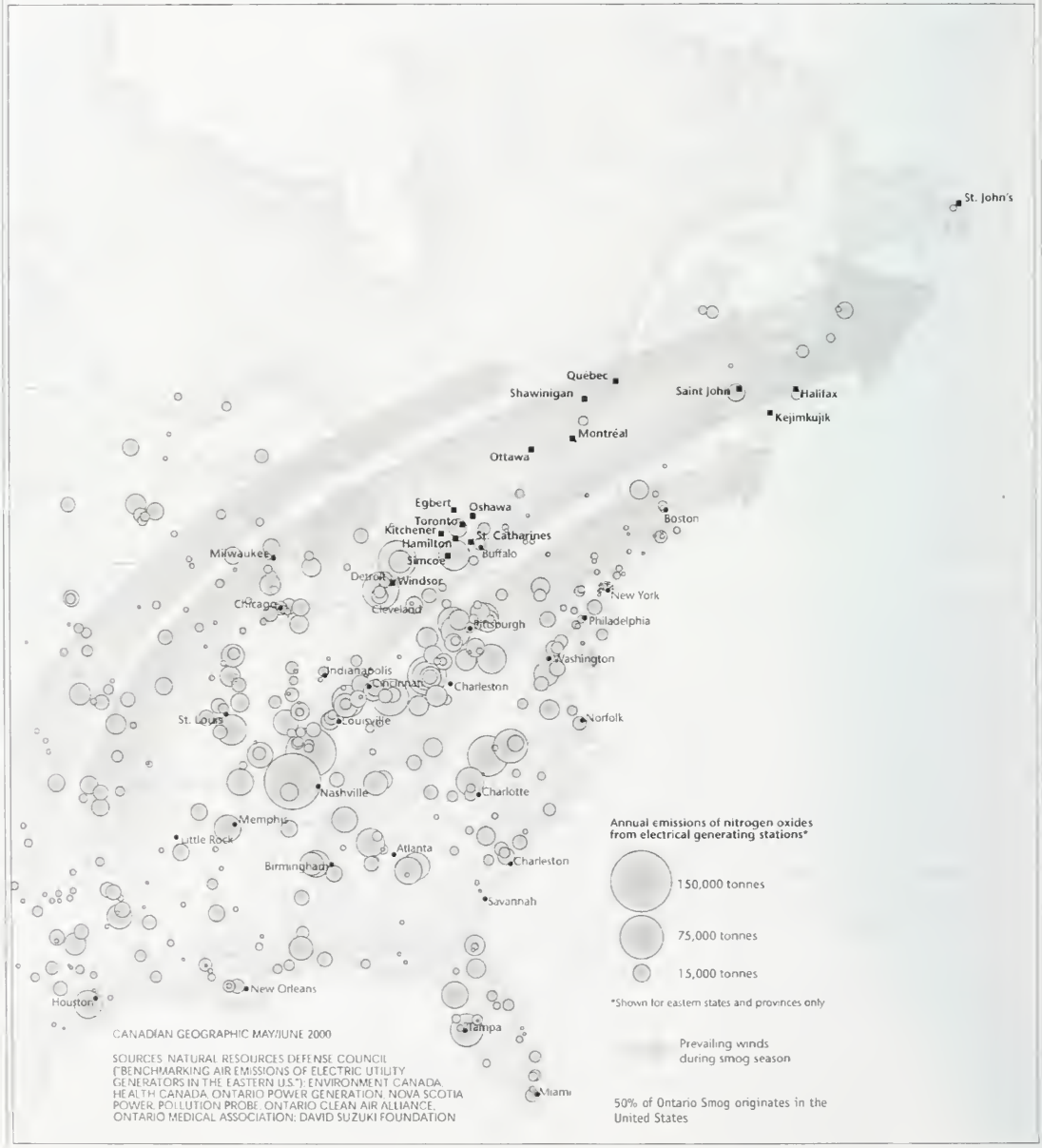
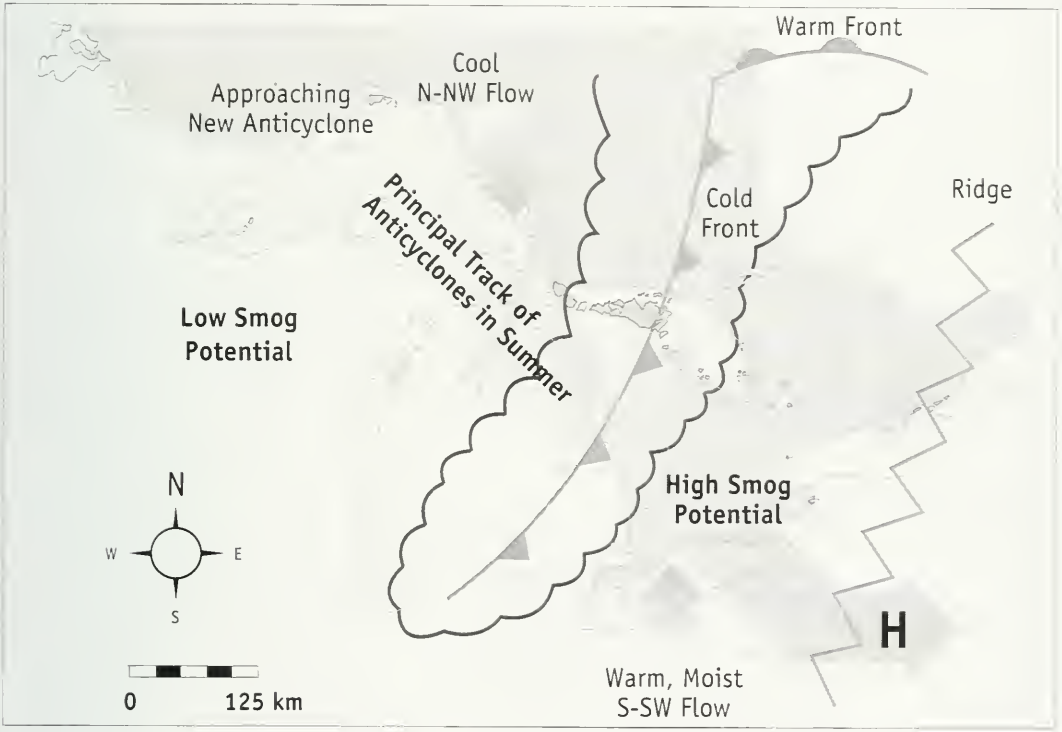


Figure 6.2

Generalized Synoptic Weather Pattern Over Southern Ontario Conducive to Elevated Pollutant Levels



conducive to episodes of smog (fine particles and ozone) over southern Ontario.

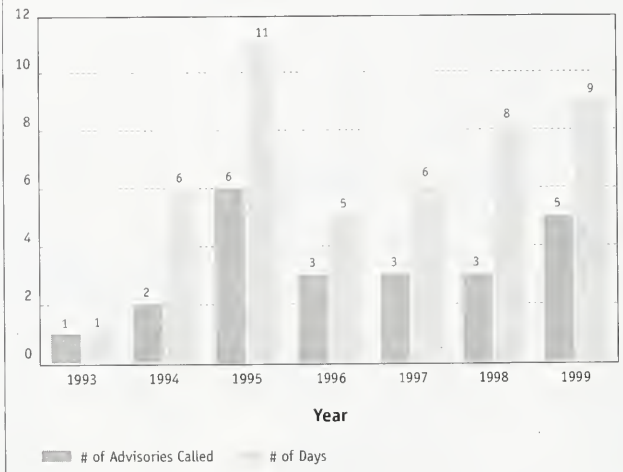
Smog advisories

Initiated in the spring of 1993 as a joint effort between the Ministry of the Environment and Environment Canada, smog advisories (formerly known as air quality advisories) are issued to the public when elevated levels of ground-level ozone are forecast. This program builds on Ontario's Air Quality Index (AQI) program which was introduced in 1988. The advisories are issued regionally by noon the day before expected elevated ozone levels. They encourage people to prevent further deterioration of air quality and outline the effects of air pollution on health and the environment. Smog advisories are made public via the news media, weather offices and weather radio. They are also available at local ministry offices and through the ministry's Web site: **www.airqualityontario.com**.

There are several ways to help reduce ozone (smog) formation. These include limiting driving through car pooling, walking, biking and combining errands; taking public transportation; avoiding excessive idling of vehicles; deferring outdoor chores that use gasoline-powered equipment; postponing the use of oil-based paints and solvents; starting

Figure 6.3

Summary of Air Quality Advisories Called (1993–1999)



charcoal with an electric starter instead of lighter fluid; and conserving energy use.

Smog advisories were issued five times in 1999. Two advisories were of one-day duration, May 30 and June 13, and two were of two-day duration, June 22-23 and September 3-4. The remaining advisory lasted for three days, July 15-17. Twenty-three advisories have been called over the seven years 1993 to 1999 ***(Figure 6.3)***. In 1993, there was one advisory lasting one day. This was followed by two advisories in 1994 covering a total of six days, six advisories in 1995 covering 11 days, three advisories in 1996 covering five days, three advisories in 1997 covering six days, three advisories in 1998 covering eight days and five advisories in 1999 covering nine days. The number and duration of smog advisories are highly dependent on summer weather conditions experienced over southern Ontario between May and September.

Summer 1999

The summer of 1999 was characterized by two significant multi-day smog episodes across southern Ontario. On these occasions, widespread elevated ozone levels persisting for three or more consecutive days prompted the ministry to issue smog advisories for July 15-17 and September 3-4. It was also the first time that the ministry issued smog advisories in September since the inception of the program in 1993.

The July 15-17 episode was not unique to Ontario but was part of a larger event that impacted most of eastern North America during the period July 13 to July 17. Sunny and hot conditions with a light southerly flow dominated the region. This allowed the transport, trans-boundary flow and accumulation of ozone and its precursors over southern Ontario. Maximum one-hour ozone levels reached 91 ppb on July 13 (Tiverton), 122 ppb on July 14 (Tiverton), 116 ppb on July 15 (Kitchener), 113 ppb on July 16 (Mandaumin and Parkhill) and 96 ppb on July 17 (Long Point). Ten sites exceeded the one-hour Ontario ozone criterion (80 ppb) over large areas of the province on July 13, 26 sites on July 14, 28 sites on July 15, 31 sites on July 16 and 12 sites on July 17. Daily fine particle ($PM_{2.5}$) levels across southern Ontario exceeded the proposed Canada-Wide Standard (CWS) of 30 $\mu g/m^3$ at 33 $\mu g/m^3$ on July 14, increasing to 41-47 $\mu g/m^3$ on July 15 and 45-58 $\mu g/m^3$ on July 16 as the airmass aged. $PM_{2.5}$ levels remained above the CWS on July 17 at 30-41 $\mu g/m^3$. A change in airmass by July 18 resulted in cleaner air across southern Ontario and ozone and fine particle levels in the fair range.

Diurnal variations of ozone and fine particle concentrations on July 14-17 for this episode at the Etobicoke South site in Toronto are shown in ***Figure 6.4***. Ozone levels exhibited strong diurnal variations with afternoon

levels in excess of the one hour ozone criterion. In contrast, fine particles, both PM_{10} and $PM_{2.5}$, showed a progressive build-up of concentrations each day over the period as the airmass aged. Figure 6.4 also reveals that about 70-80 per cent of the fine particle concentrations during the episode were in the respirable range (i.e. $PM_{2.5}$).

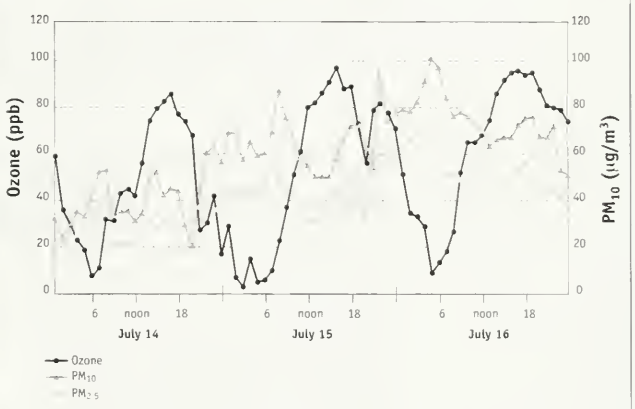
The September 3-4 episode, was also characterized by sunny, hot and humid conditions coupled with light southwest winds and resulted in elevated air pollution due to ground-level ozone and fine particles across southern Ontario. As the airmass became nearly quasi-stationary and polluted, the ministry issued a smog advisory on the afternoon of September 2 for the following day in anticipation of widespread elevated pollution levels over southern Ontario. By the morning of September 3, a nearly stagnant weather pattern with light winds dominated the Great Lakes Region and resulted in widespread occurrence of fog over the entire Great Lakes Basin. Maximum one-hour ozone levels reached 145 ppb on September 2 (Sarnia), 122 ppb on September 3 (Stouffville) and 109 ppb on September 4 (Parkhill). Eighteen sites exceeded the one-hour Ontario ozone criterion on September 2, 29 sites on September 3 and 24 sites on September 4. Daily fine particle ($PM_{2.5}$) levels during this episode reached about 33 $\mu g/m^3$ across southern Ontario on September 2, 33-45 $\mu g/m^3$ on September 3 and 33-46 $\mu g/m^3$ on September 4.

Winter 1999

Fine particle episodes across southern Ontario occurred on two occasions, February 27, 1999 and November 19, 1999, respectively. Both events had widespread occurrence of elevated fine particle levels in excess of the proposed Canada-Wide Standard of 30 $\mu g/m^3$ on a 24-hour basis. Levels

Figure 6.4

Ozone and Particle Levels at Etobicoke South July 14, 15 and 16, 1999



ranged from 31 to 40 $\mu g/m^3$ on February 27 and from 31 to 39 $\mu g/m^3$ on November 19. Meteorological analysis of the two periods indicate that the episodes were largely the result of stagnating weather conditions and the accumulation of local emissions in the air mass.

Chapter 7

Special Purpose Monitoring

Air toxics are substances that, based upon their toxicity and concentration in the ambient air, have the potential to cause harm to humans and the ecosystem. Air toxics include certain volatile organic compounds (VOCs) that warrant special concern because they are capable of being transported very long distances in the atmosphere and play an important role in the formation of ground-level ozone and fine particles. VOCs are defined technically as organic compounds having a saturation vapour pressure greater than 10^{-1} Torr at 25°C and standard atmospheric pressure.

The VOC monitoring data are used to support many key ministry initiatives. Firstly, VOC data are critical to the development and review of ambient air quality criteria (AAQC). Current exposure levels can also be used to identify regions of the province where potential compliance problems may occur. Secondly, measurements from a variety of ambient air settings (rural, suburban and urban) can be used to assess general environmental quality and to characterize long-range transport contributions. Thirdly, long-term measurements are desirable to track reductions of ozone precursor VOCs, as projected from VOC emission changes outlined in Ontario's Anti-Smog Action Plan, and to reconcile emission inventories.

VOCs are emitted into the atmosphere from a variety of sources, including vehicles, fossil fuel combustion, steel-making, petroleum refining, fuel-refilling, industrial and residential solvent use, paint application, manufacturing of synthetic materials (e.g., plastics, carpets), food processing, agricultural activities and wood processing and burning. Specialized, non-routine monitoring and analytical techniques are required to measure VOCs because they are usually present in the atmosphere in gaseous form at ultra-trace concentrations.

Since 1997, VOC monitoring in Ontario has been a co-operative effort between the Ministry of the Environment and Environment Canada (Environmental Protection Service). For the purposes of this report, only 1999 data from eight rural, suburban or urban monitoring stations are included in the discussion. Data were excluded from other sites having less extensive data coverage and from sites designated as being strongly source-influenced. The monitoring sites described in this report are shown in ***Figure 7.1.***

VOC samples are collected by automatically drawing ambient air into evacuated stainless steel canisters over a 24-hour period (midnight to midnight), following the National Air Pollution Surveillance sampling schedule (every sixth day). Concentrations for 143 selected VOCs, as listed in ***Table 7.1***, were reported for each sample. Summary statistics were calculated for each of the selected VOCs at each of the eight ambient sampling sites. These statistics appear in the separate appendix document.

Figure 7.1
Location of Ambient VOC Monitoring Sites (1999)

Figure 7.2 shows the percentage distribution of VOCs by compound class at three types of sampling sites: urban (Sarnia); suburban (Stouffville); and rural (Point Petre) for 1999. Alkanes are the predominant VOC class, accounting for about one-half of the total mass of samples for the urban and suburban sites. In comparison to the urban and suburban sites, the rural site, Point Petre, has a higher percentage of halogens. The Point Petre site is exposed to air masses consisting of VOCs with extended atmospheric residence times and subject to long-range transport. The urban and suburban profiles are remarkably similar with little variation noted between VOC class.

Another approach at assessing the relative importance of individual VOCs and the site-to-site variability is illustrated by box-and-whisker plots ***(Figure 7.3)***. Again, the distinction between rural versus urban and suburban sites is shown. At rural sites, median concentrations (ranging from 0.5 to 2.0 $\mu g/m^3$) are typically one-half those observed at suburban and urban sites (ranging from 1.0 to 5.0 $\mu g/m^3$). Likewise, the variability in VOC concentrations is greatest at suburban and urban sites, while rural site concentrations have less variability because these sites are less susceptible to nearby source influences.

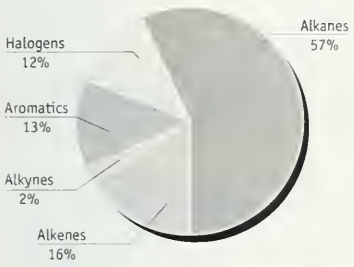
Table 7.1 List of Volatile Organic Compounds (VOCs)

Alkanes	Alkenes	Alkynes	Aromatics	Halogens
Ethane	Ethylene	Acetylene	Benzene	Freon11
Propane	1,3-Butadiene	1-Butyne	Toluene	Dibromomethane
Butane	1-Butene + Isobutene		Styrene	Carbon tetrachloride
Isobutane	trans-2-Butene		Ethylbenzene	Dibromochloromethane
Cyclopentane	cis-2-Butene		Indane	Bromoform
Pentane	Cyclopentene		Iso-Propylbenzene	Bromodichloromethane
Isopentane	Isoprene		n-Propylbenzene	Chloroform
2,2-Dimethylpropane	trans-2-Pentene		sec-Butylbenzene	Chloromethane
Cyclohexane	2-Methyl-1-Butene		tert-Butylbenzene	Dichloromethane
Methylcyclopentane	cis-2-Pentene		iso-Butylbenzene	Freon22
2,2-Dimethylbutane	1-Pentene		Hexylbenzene	Bromomethane
2,3-Dimethylbutane	2-Methyl-2-Butene		m+p-Xylene	Bromotrichloromethane
3-Methylpentane	Cyclohexene		o-Xylene	cis-1,2-Dichloroethylene
2-Methylpentane	1-Methylcyclopentene		3-Ethyltoluene	Bromoethane
Hexane	2-Ethyl-1-Butene		4-Ethyltoluene	Tetrachloroethylene
Methylcyclohexane	cis-2-Hexene		1,3,5-Trimethylbenzene	Chloroethane
2,2,3-Trimethylbutane	1-Hexene		2-Ethyltoluene	Trichloroethylene
3-Methylheptane	3-Methyl-1-Pentene		1,2,4-Trimethylbenzene	trans-1,2-Dichloroethylene
2-Methylheptane	trans-4-Methyl-2-Pentene		1,2,3-Trimethylbenzene	1,2-Dichloroethane
4-Methylheptane	cis-4-Methyl-2-Pentene		1,3-Diethylbenzene	1,1-Dichloroethane
Heptane	4-Methyl-1-Pentene		Napthalene	1,1,2-Trichloroethane
3-Methylhexane	trans-3-Methyl-2-Pentene		p-Cymene	Freon114
2,2-Dimethylpentane	trans-2-Hexene		1,4-Diethylbenzene	Freon12
2,4-Dimethylpentane	cis-3-Methyl-2-Pentene		n-Buytlbenzene	1,1-Dichloroethylene
2,3-Dimethylpentane	1-Methylcyclohexene		1,2-Diethylbenzene	Vinyl chloride
2-Methylhexane	cis-2-Heptene			1,1,1-Trichloroethane
cis-1,4-Dimethylcyclohexane	trans-3-Heptene			1,1,2,2-Tetrachloroethane
+ trans-1,3-Dimethylcyclohexane	1-Heptene			Trans-1,3-Dichloropropene
cis-1,3-Dimethylcyclohexane	cis-3-Heptene			1,2-Dichloropropane
trans-1,4-Dimethylcyclohexane	trans-2-Heptene			cis-1,3-Dichloropropene
trans-1,2-Dimethylcyclohexane	1-Octene			Hexachlorobutadiene
2,2,4-Trimethylpentane	cis-2-Octene			1,4-Dichlorobutane
2,2-Dimethylhexane	trans-2-Octene			Chlorobenzene
Octane	1-Nonene			1,3-Dichlorobenzene
2,4-Dimethylhexane	1-Decene			1,4-Dichlorobenzene
2,5-Dimethylhexane	Propylene			1,2,4-Trichlorobenzene
2,3,4-Trimethylpentane				1,2-Dichlorobenzene
2,2,5-Trimethylhexane				
Nonane				
3,6-Dimethyloctane				
Decane				
Undecane				
Dodecane				

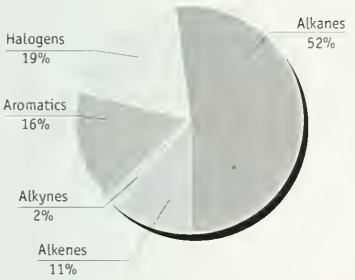
Alkanes are saturated hydrocarbons in which all carbon atoms form a single bond with other atoms. Alkenes are unsaturated hydrocarbons in which some carbon atoms form a double bond with other carbon atoms. Alkynes are unsaturated hydrocarbons in which some carbon atoms form a triple bond with other carbon atoms. Aromatics are compounds where the double-bond carbon atoms occur in a ring-type pattern. Halogenated compounds are hydrocarbons which add or substitute one or more atoms of chlorine, bromine, fluorine or iodine. Samples from one site, Windsor (College), are also analysed for carbonyls (hydrocarbons which contain an oxygen atom forming a double bond with a carbon atom). See the 1999 Appendix Report for annual summary statistics.

Figure 7.2

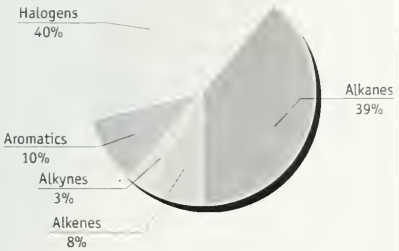
Percentage Distribution of VOCs by Class at Sites Across Ontario (1999)



Urban (Sarnia)



Suburban (Stouffville)



Rural (Point Petre)

Figure 7.3

Box Plot for Selected VOC Concentrations at an Urban, Suburban and Rural Site (1999)

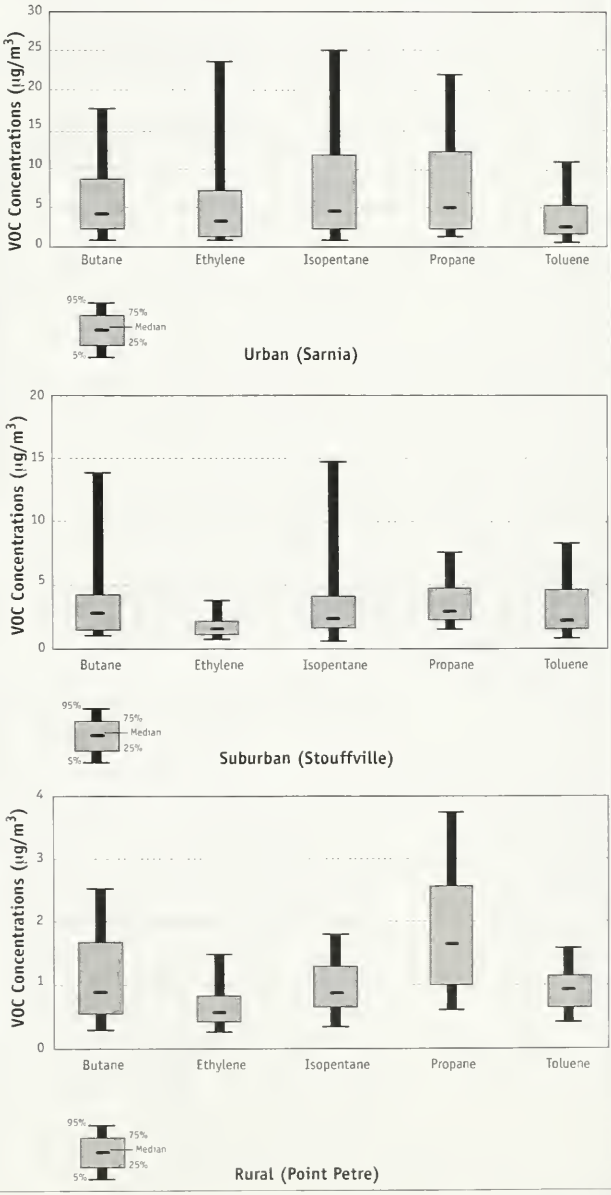


Figure 7.4

Average Concentrations of Benzene, Toluene and Ortho-xylene in Ontario (1993–1999)

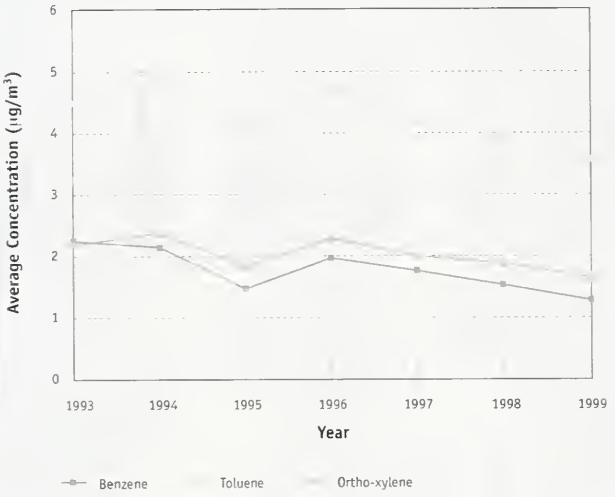
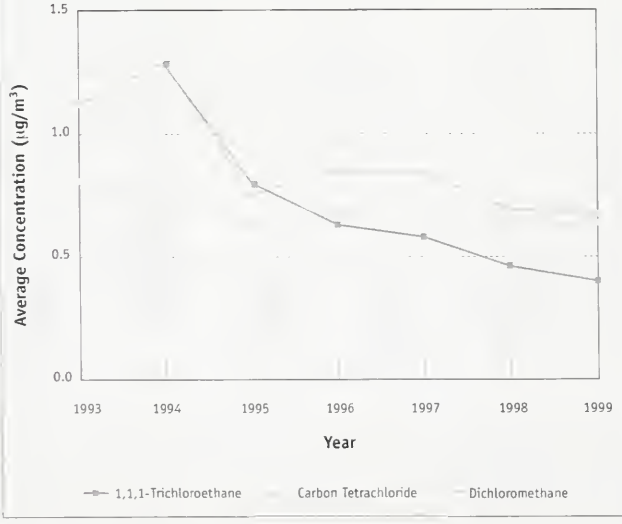


Figure 7.5

Ambient Average Concentrations of 1,1,1-Trichloroethane, Carbon Tetrachloride and Dichloromethane in Ontario (1993–1999)



Figures 7.4 and ***7.5*** show trends in selected VOCs at ambient sites for the period 1993 to 1999. Benzene, toluene and ortho-xylene concentrations are shown in ***Figure 7.4.*** These toxics are emitted primarily from automobile exhausts and by the petrochemical industry. There has been a fairly steady overall downward trend for benzene, toluene and ortho-xylene, especially during the 1996 to 1999 period.

The compounds whose concentrations are shown in ***Figure 7.5*** are generally used as solvents for various purposes. Such solvent use is subject to increasing control in Ontario, and the result is seen in the steady downward trend for 1,1,1-trichloroethane, carbon tetrachloride and dichloromethane.

In summary, concentrations of VOCs at ambient sites in Ontario exist at trace levels well below existing ministry criteria levels.

Chapter 8

International/ National/Regional Air Quality Perspective

The purpose of this section is to reflect on the state of Toronto's air quality in comparison to that of other cities from an international, national, and regional perspective. In early 2000, the Ontario Ministry of the Environment requested 1999 ambient air quality data from 50 cities in some 25 countries worldwide. Thirty-one cities responded (as displayed in ***Figure 8.1***) with air quality data that could be used in a subjective comparison with Toronto. Their metropolitan populations ranged from about 150,000 (Saint John, New Brunswick) to 11 million (Sao Paulo, Brazil). The international perspective does not necessarily portray a fair representation of cities around the world as some of the key cities with high pollution levels are not reported here.

Data from all available monitoring sites within the metropolitan areas of each city were requested because it was felt that this would be more representative of average city air quality than data from a select number of sites. Monitoring methods and siting procedures may vary from country to country, therefore comparisons among nations are subject to caution. Since the form of air quality standards may vary from country to country, the inter-city comparisons represented here are referenced to ambient air quality criteria (AAQC) for Ontario and the national ambient air quality standards (NAAQS) for the United States.

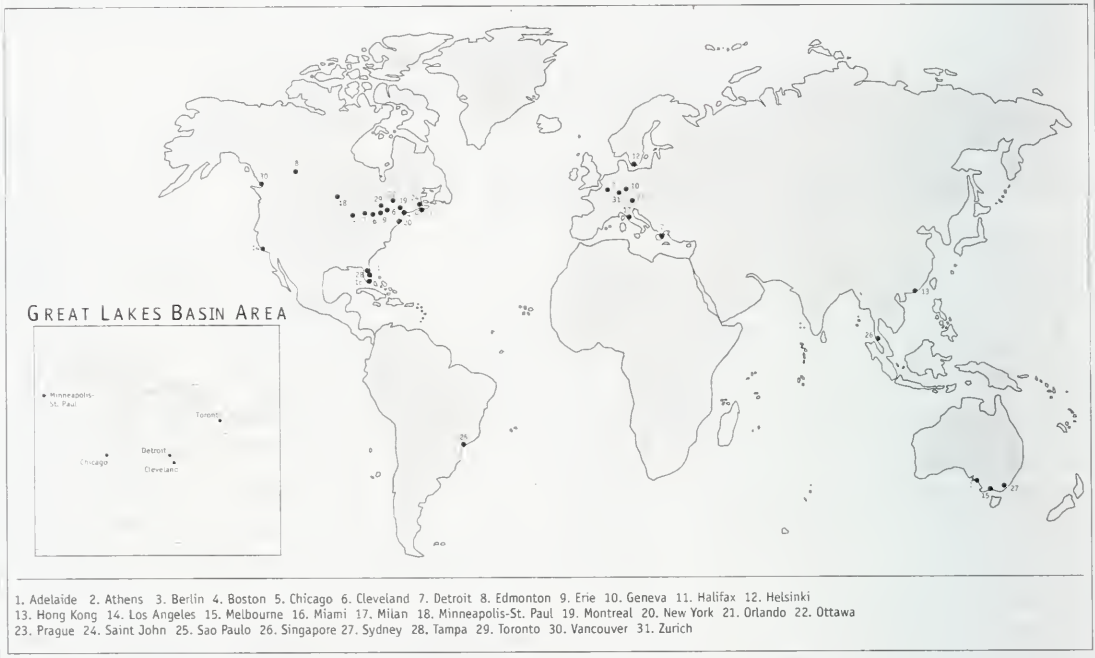
For the most recent available reporting year – 1999 – levels of the criteria pollutants, including ground-level ozone (O_3), inhalable particles (PM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO) and sulphur dioxide (SO_2) were compared worldwide. Ten-year trends for the period 1990-1999 were also analyzed. A more detailed analysis of the state of air quality at selected cities within the Great Lakes Basin area was also examined by comparing and ranking air quality levels at five cities within the basin area. The cities included are Cleveland, Chicago, Minneapolis-St. Paul, Detroit and Toronto.

Toronto: An International and National Perspective

Ground-level ozone (O_3)

Maximum one-hour O_3 levels for 1999 are displayed for 27 cities in ***Figure 8.2***. The highest one-hour O_3 concentration during 1999 was recorded in Hong Kong (174 ppb), followed closely by Athens (172 ppb) and Sao Paulo (171 ppb). Helsinki recorded the lowest ozone maximum at only 73 ppb. Of the 27 cities reporting, nine exceeded the U.S. NAAQS (120 ppb) and 25 exceeded the more restrictive Ontario one-hour AAQC (80 ppb). Toronto's maximum one-hour O_3 concentration (113 ppb) ranked 14th best out of 27 cities during 1999. From a national perspective, out of seven Canadian cities,

Figure 8.1
Cities Around the World Reporting Air Quality (1999)



1. Adelaide 2. Athens 3. Berlin 4. Boston 5. Chicago 6. Cleveland 7. Detroit 8. Edmonton 9. Erie 10. Geneva 11. Halifax 12. Helsinki 13. Hong Kong 14. Los Angeles 15. Melbourne 16. Miami 17. Milan 18. Minneapolis-St. Paul 19. Montreal 20. New York 21. Orlando 22. Ottawa 23. Prague 24. Saint John 25. Sao Paulo 26. Singapore 27. Sydney 28. Tampa 29. Toronto 30. Vancouver 31. Zurich

Montreal recorded the highest one-hour maximum for O_3 at 125 ppb in 1999, followed by Toronto (113 ppb). Vancouver recorded the lowest maximum for O_3 at 74 ppb and was the only Canadian city that did not exceed Ontario's one hour O_3 AAQC of 80 ppb during 1999.

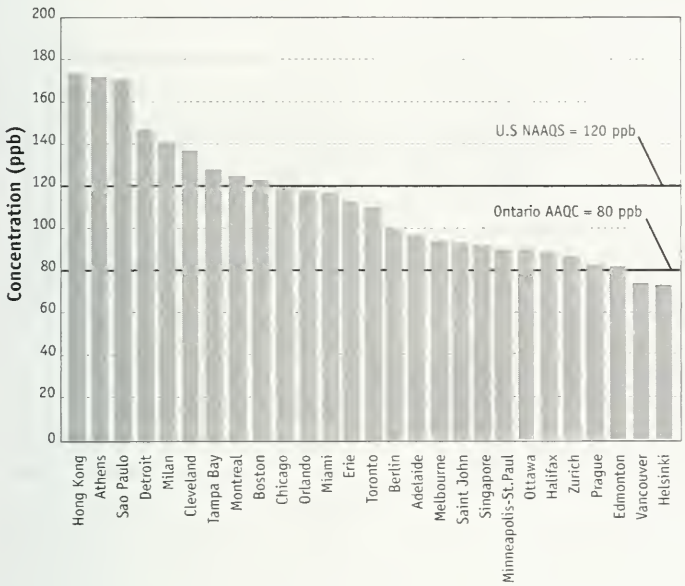
The ten-year range (1990-1999) for one-hour maximum O_3 concentrations in 21 cities is shown in ***Figure 8.3***. Los Angeles and Detroit were at the higher end of the scale while Edmonton and Helsinki were at the lower end of the scale. Over the 10-year period, Toronto ranked 11th best out of 21 cities for maximum one-hour O_3 concentrations. Nationally over the ten-year period, Toronto recorded the highest O_3 levels followed by Montreal, whereas Edmonton recorded the lowest O_3 levels. In addition to the year to year variability in meteorological factors that are conducive to high ozone concentrations during episode events, the combination of local emissions and, in particular, long-range transport from the United States greatly influence the magnitude of O_3 concentrations recorded in the Windsor-Quebec City corridor, such as those experienced in Toronto and Montreal.

Inhalable particles (PM_{10})

Composite annual means of PM_{10} levels for 1999 are displayed for 22 cities in ***Figure 8.4***. The highest composite annual mean was recorded in Hong Kong (58.9 $\mu g/m^3$), followed by Sao Paulo (48.0 $\mu g/m^3$). Hong Kong was the only city that exceeded the U.S. NAAQS of 50 $\mu g/m^3$ in 1999. Vancouver recorded the

Figure 8.2

Maximum One-Hour Ozone Concentration in Selected Cities Around the World (1999)



lowest composite annual mean (11.0 µg/m^3). Toronto ranked fifth best out of 22 cities when comparing composite annual mean PM_{10} levels during 1999. For the 5 Canadian cities examined, Saint John, New Brunswick recorded the highest PM_{10} composite annual mean (25.5 µg/m^3) while Vancouver recorded the lowest composite annual mean (11.0 µg/m^3). Toronto's PM_{10} composite annual mean was 22.0 µg/m^3 in 1999. Overall, PM_{10} concentrations in Toronto were similar to those observed at the other Canadian cities except for Vancouver where PM_{10} levels were well below the national average.

The ten-year range (1990-1999) in composite annual mean PM_{10} levels for 15 cities is shown in ***Figure 8.5***. Sao Paulo and Hong Kong were at the higher end of the range of

Figure 8.3

10-Year Range of Maximum One-Hour Ozone Levels in Selected Cities Around the World (1990–1999)

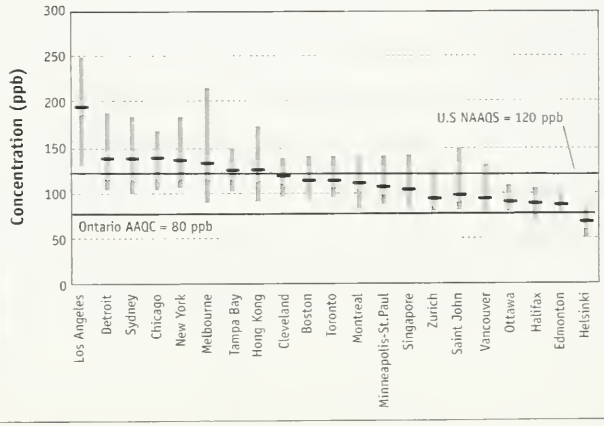


Figure 8.4

Composite Annual Mean of PM_{10} Concentrations in Selected Cities Around the World (1999)

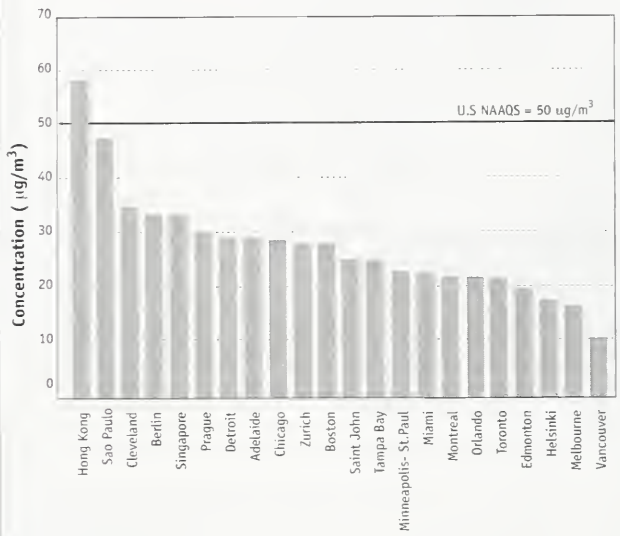
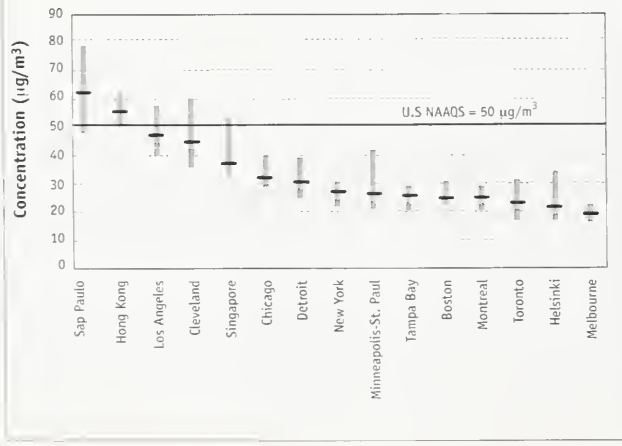


Figure 8.5

10-Year Range of Composite Annual Mean for PM_{10} Concentrations in Selected Cities Around the World (1990-1999)



composite annual means reported. Of the 15 cities compared, Toronto ranked third best internationally which was slightly better than Montreal from a national perspective. PM_{10} may be directly emitted by a source or formed in the atmosphere by the transformation of gaseous precursor emissions, such as NO_x and SO_2. Long range transport of these precursors from the mid-western states of the U.S. contribute to the PM levels in the Windsor-Quebec City corridor, however these concentrations also result from local emissions from human activity and natural sources. The Canadian cities maintained concentration levels far below the U.S. NAAQS over the ten-year period.

Nitrogen dioxide (NO_2)

Composite annual means of NO_2 levels for 1999 are shown for 27 cities in ***Figure 8.6***. Milan (35 ppb), Hong Kong (34 ppb) and Athens (30 ppb) recorded the highest NO_2 composite annual means for 1999 while Tampa Bay (9 ppb), Adelaide (6 ppb) and Saint John (3 ppb) recorded the lowest levels. Toronto's composite annual mean NO_2 concentration (24 ppb) ranks 22nd out of 27 cities however, it is still far below the U.S. NAAQS of 53 ppb. Overall, none of the 27 cities exceeded the U.S. NAAQS for NO_2 during 1999. From a national perspective, Toronto recorded the highest composite annual mean (24 ppb) for NO_2 in 1999, followed by Edmonton (21 ppb) and Halifax (19 ppb). Saint John recorded the lowest composite annual mean (3 ppb) during 1999.

The ten-year range of composite annual mean NO_2 concentrations for 20 cities is presented in ***Figure 8.7***. At the higher end of the range are Los Angeles and New York while at the lower end are Melbourne and Saint John. Toronto ranked 15th out of the 20 cities compared. In Canada, Toronto had the highest NO_2 composite annual mean during the 1990s

while Saint John had the lowest. Higher levels of NO_2 are found in larger urban centres like Toronto because of population density and motor vehicle emissions.

Carbon monoxide (CO)

Maximum one-hour CO levels for 1999 are displayed for 25 cities in ***Figure 8.8***. Although the highest one-hour concentration during 1999 was recorded in Milan (18.0 ppm), followed closely by Sao Paulo (17.9 ppm), the levels remained well below the Ontario AAQC of 30 ppm and the U.S. NAAQS of 35 ppm. Internationally, Toronto ranked 9th best out of 25 cities in 1999, while Ottawa recorded the lowest CO maximum (3.0 ppm) from both an international and national perspective. In 1999, Edmonton recorded the highest one-hour maximum for CO (9.3 ppm) of the seven Canadian cities compared.

The ten-year range (1990-1999) in maximum CO concentration for 18 cities is shown in ***Figure 8.9***. Sao Paulo and Cleveland were at the higher end of the scale while Halifax and Zurich were at the lower end. Over the ten-year period, Toronto ranks 10th best out of 18 cities for maximum one-hour CO concentrations. During the 1990s, Toronto did not exceed the Ontario AAQC or U.S. NAAQS for CO. Nationally over the 10-year period, Edmonton recorded the highest CO levels while Halifax recorded the lowest CO levels. Toronto ranks 5th out of seven Canadian cities during the 1990s. CO levels are strongly influenced by local vehicle emissions.

Sulphur dioxide (SO_2)

Composite annual means of SO_2 levels for 1999 are shown for 26 cities in ***Figure 8.10***. The highest composite annual mean (8 ppb) was recorded in both Hong Kong and Singapore while Helsinki, Melbourne and Miami recorded the lowest composite annual mean (1 ppb) in 1999. Toronto ranked 16th best out of 26

Figure 8.6

Composite Annual Mean of Nitrogen Dioxide Concentrations in Selected Cities Around the World (1999)

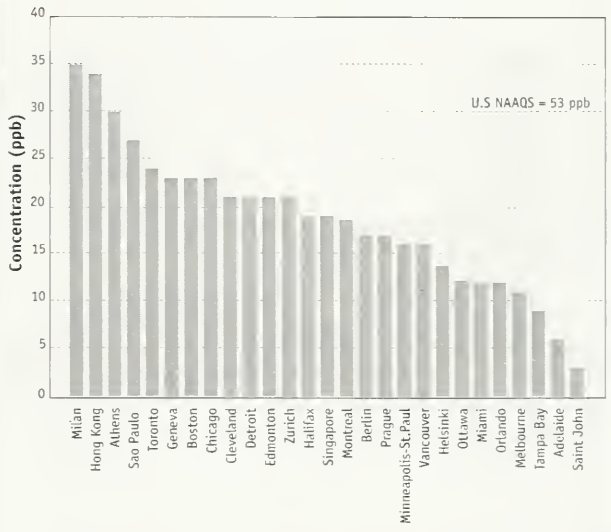


Figure 8.7

10-Year Range of Composite Annual Mean for Nitrogen Dioxide Concentrations in Selected Cities Around the World (1990–1999)

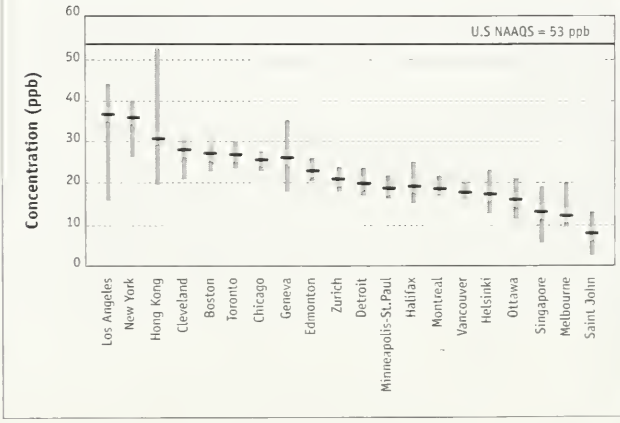


Figure 8.8

Maximum 1-Hour Carbon Monoxide Concentrations in Selected Cities Around the World (1999)

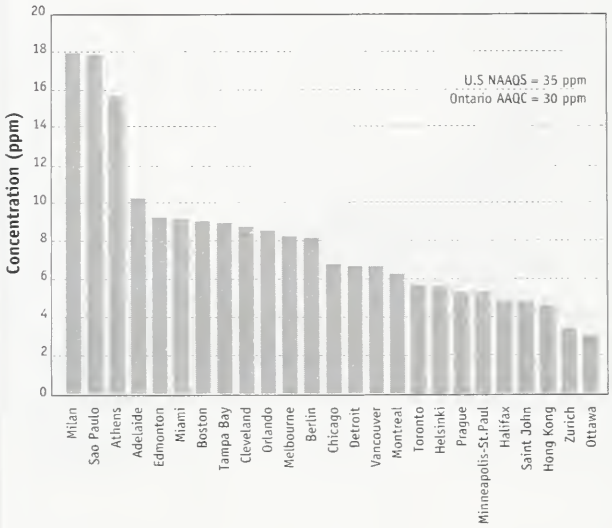
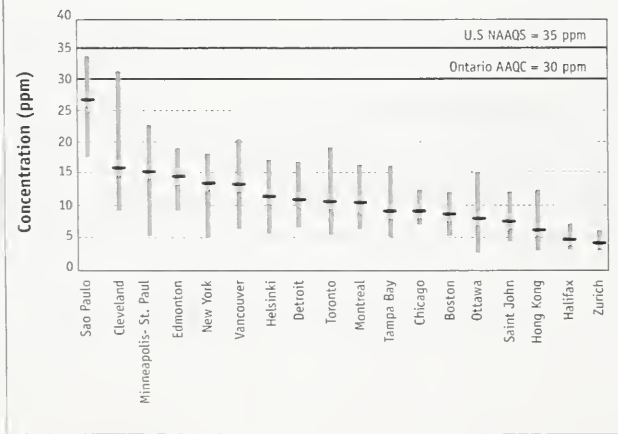


Figure 8.9

10-Year Range of Maximum 1-Hour Carbon Monoxide Levels in Selected Cities Around the World (1990–1999)



cities when comparing composite annual mean SO_2 levels during 1999. All of the cities recorded levels below the Ontario AAQC of 20 ppb and the U.S. NAAQS of 30 ppb. For the six Canadian cities examined, Saint John recorded the highest SO_2 composite annual mean (6 ppb) while Vancouver recorded the lowest composite annual mean (2 ppb) in 1999. Toronto's composite annual mean for SO_2 in 1999 was 5 ppb.

The ten-year range (1990-1999) in composite annual mean SO_2 levels for 21 cities is displayed in ***Figure 8.11***. New York was at the higher end of the range of annual means reported while at the lower end was Melbourne. Of the 21 cities compared, Toronto ranked 10th best internationally. In Canada, Saint John had the highest SO_2 composite annual mean while Vancouver and Edmonton had the lowest composite annual mean for SO_2 from 1990-1999. Toronto ranked 3rd best out of the six Canadian cities during the 1990s.

The Great Lakes Basin Area: A Regional Perspective

A regional comparison of five key pollutants in five cities within the Great Lakes Basin area (Figure 8.1) over a ten-year period (1990-1999) is presented here. The levels for the criteria pollutants (O_3, PM_{10}, NO_2, CO and SO_2) are examined in Chicago, Cleveland, Detroit, Minneapolis-St. Paul and Toronto, and subsequently ranked accordingly in order to collectively compare the air quality within the five selected cities.

The range in ambient levels for the five criteria pollutants over the 10-year period, 1990-1999 is displayed graphically in Figures 8.3, 8.5, 8.7, 8.9, and 8.11. Toronto finished in 1st place for PM_{10}, recording the lowest overall levels and for O_3, CO and SO_2, Toronto was positioned at the lower end of the range

and finished 2nd best. For the remaining criterion contaminant, NO_2, Toronto placed behind Cleveland, recording the second highest NO_2 concentration in the Great Lakes Basin area.

The ranking of the cities (based on the concentration level of the pollutant measured in the ambient air) ranged from one (representing the best air quality) to five (representing the poorest air quality). The rankings were summed for each city to result in a total score. The higher the total score, the worse the air quality.

The overall ranking of the five cities in the Great Lakes Basin area for the criteria pollutant levels for 1990-1999 is displayed in ***Table 8.1***. Minneapolis-St. Paul finished in 1st place representing the best air quality in the region, closely followed by Toronto in 2nd place. Cleveland placed 5th recording the overall highest concentrations of the criteria pollutants examined in the area.

Summary

Toronto's air quality is generally represented quite well when compared to other cities around the world for 1999 and, for the ten-year period of 1990-1999. This is further emphasized in the regional perspective of the Great Lakes Basin area where Toronto ranks in second place for best overall air quality. From a Canadian perspective, meteorological and topographical factors influence the levels of pollutants observed mainly in the Windsor-Quebec City corridor. Data analysis strongly implicates neighbouring U.S. states as being significant contributors to high levels of ozone, PM_{10} and its precursors in southern Ontario, including Toronto.

Figure 8.10

Composite Annual Mean of Sulphur Dioxide Concentrations in Selected Cities Around the World (1999)

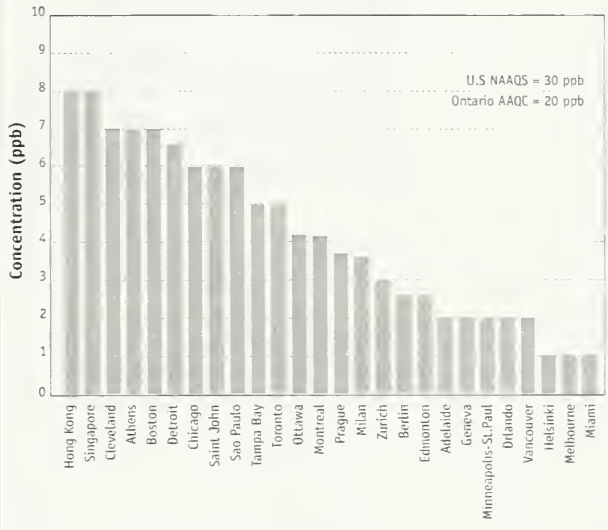


Figure 8.11

10-Year Range of Composite Annual Mean for Sulphur Dioxide Concentrations in Selected Cities Around the World (1990–1999)

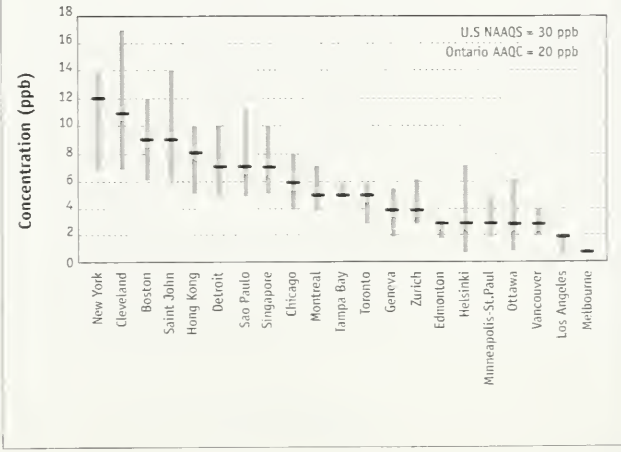


Table 8.1 Ranking of Metropolitan Areas in the Great Lakes Basin Area According to Criteria Pollutant Levels (1990-1999)

Metropolitan Area	O_3	PM_{10}	NO_2	CO	SO_2	Total Score	Overall Ranking
Chicago	4	4	3	1	3	15	3
Cleveland	3	5	5	5	5	23	5
Detroit	5	3	2	3	4	17	4
Minneapolis-St. Paul	1	2	1	4	1	9	1
Toronto	2	1	4	2	2	11	2

Individual rankings are summed for each metropolitan area to determine an overall score.

Future Directions

Since the first edition of this report in 1971, there has been consistent improvement in Ontario's air quality even while there have been increases in population, economic activity and vehicular travel. Significant decreases have been achieved for sulphur dioxide, carbon monoxide, total suspended particulate matter, nitrogen oxides and total reduced sulphur compounds.

Encouraging as this is, there is still a great deal of work to be done, and the Ontario government is directing increased emphasis to ozone and inhalable and respirable particles (PM_{10} and $PM_{2.5}$), which recent scientific evidence suggests have significant health effects.

In 1999 there were a number of days on which PM_{10} levels exceeded the Ontario 24-hour interim PM_{10} criterion of 50 $\mu g/m^3$ and $PM_{2.5}$ levels exceeded the proposed Canada-Wide Standard for $PM_{2.5}$ of 30 $\mu g/m^3$ on a 24-hour basis. For ambient urban sites the highest percentage of days – four to six per cent – occurred in Windsor and Hamilton respectively, cities strongly influenced by long-range transport, trans-boundary effects, and local sources.

Data analysis strongly implicates neighbouring U.S. states – namely Ohio, Michigan, Illinois and New York – as significant contributors to high levels of inhalable particles and ozone in southern Ontario. The quantitative contributions from long-range transport and trans-boundary movement of air pollution and from local sources need further assessment.

Due to the potential health and environmental effects of these two key components of smog, continued monitoring is required to evaluate trends and determine the effectiveness of reduction and abatement strategies.

Ontario has begun to change its existing monitoring network by deploying real-time monitors for inhalable and respirable particles. These are being phased in over the next few years; the ministry hopes to equip all AQI designated sites with these monitors. In 1999 there were 24 monitors of $PM_{10}/PM_{2.5}$ (11 PM_{10} and 13 $PM_{2.5}$) for which 18 of these monitors provided sufficient data for analysis. The collection and assessment of this data will allow for improvement to the reporting of important air quality information to all Ontarians.

The Ontario government has committed itself fully to improving air quality with a series of initiatives. Foremost of these is its Drive Clean program, which started in spring 1999 and required emission testing of light-duty vehicles, followed by repairs where necessary. In January 2000, the ministry launched its new heavy-duty vehicle emissions testing program to reduce emissions from trucks, buses and other heavy-duty vehicles.

On May 1, 2000 an enhanced smog alert and AQI program was unveiled. This enhanced program provides Ontarians with improved reporting through comprehensive and timely air quality readings and forecasts.

As of May 1, 2000, all electric power generation companies and their facilities in

Ontario's electricity sector must report annually on emissions of nitrogen oxides, sulphur dioxide and other substances such as mercury and carbon dioxide.

Other ongoing activities include:

- Ontario's Anti-Smog Action Plan, a government-industry partnership that commits 44 organizations to the reduction of smog-causing emissions;
- updated air quality standards and regulations to make them better, clearer and stronger, including a standard for inhalable particles;
- less polluting blends of gasoline in 18,000 fewer tonnes of smog-causing compounds annually;
- strong environmental protection measures being built into the design of a competitive electricity market;
- $3 million spent since 1998 on the province's air monitoring network, as well as another $2 million for new mobile air monitoring platforms;
- public education, including the Partners in Air program, created for high school students to learn about air pollution and meteorology; and
- an ongoing campaign to persuade neighbouring U.S. states to toughen their air quality regulations – which would lessen trans-boundary pollution.

Along with the contributions of concerned citizens, organizations and industries, these initiatives will go a long way toward improving the quality of Ontario's air.

Glossary

Acidic deposition refers to deposition of a variety of acidic pollutants (acids or acid-forming substances such as sulphates and nitrates) on biota or land or in waters of the earth's surface.

Air Quality Index real-time information system that provides the public with an indication of air quality in major cities across Ontario.

AQI station continuous monitoring station in a built up area, used to inform the public of air quality levels on a real-time basis; station reports on criteria pollutants.

Air Pollution Index basis of Ontario's alert and control system to warn of deteriorating air quality; derived from 24-hour running averages of sulphur dioxide and suspended particles.

Airshed a geographical region of influence or spatial extent of the air pollution burden.

Ambient air outdoor or open air.

Carcinogen an agent that incites carcinoma (cancer) or other malignancy.

Continuous pollutant contaminant for which a continuous record exists; effectively, pollutants that have hourly data (maximum 8760 values per year).

Continuous station where pollutants are measured on a real-time basis and data determined hourly (as for ozone, sulphur dioxide).

Criterion maximum concentration or level (based on potential effects) of contaminant that is desirable or considered acceptable in ambient air.

Daily pollutant contaminant with a 24-hour or daily value (maximum 365 values per year).

Detection limit minimum concentration of a contaminant that can be determined.

Exceedance violation of the pollutant levels permitted by environmental protection criteria.

Fossil fuels natural gas, petroleum, coal and any form of solid, liquid or gaseous fuel derived from such materials for the purpose of creating heat.

Geometric mean statistic of a data set calculated by taking the nth root of the product of all (n) values in a data set. Provides a better indication than arithmetic mean of the central tendency for a small data set with extreme values.

Global warming long-term rise in the average temperature of the earth; principally due to an increase in the buildup of carbon dioxide and other gases.

Ground-level ozone colourless gas formed from chemical reactions between nitrogen oxide and hydrocarbons in the presence of sunlight near the earth's surface.

Inhalable particles represents up to 60 per cent of the total suspended particulate matter; composed of both coarse (diameter 2.6 to 10.0 microns) and fine (diameter < 2.5 microns) particles; also referred to as PM_{10}.

Micron a millionth of a metre.

Median middle value of a set of numbers arranged in order of magnitude.

Monthly pollutant contaminant for which there exists only a monthly (30-day) value (maximum 12 values per year).

Non-continuous station station that measures pollutant concentration on a daily, six-day frequency or monthly cycle (as for total suspended particulate matter).

Ozone episode day a day on which widespread (hundreds of kilometres) elevated ozone levels (greater than 80 ppb maximum hourly concentration) occur simultaneously.

Particulate matter refers to any airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 microns.

Percentile value percentage of the data set that lies below the stated value; if the 70 percentile value is 0.10 ppm, then 70 per cent of the data are equal to or below 0.10 ppm.

Photochemical oxidant Air pollutants formed by the action of sunlight on oxides of nitrogen and VOCs.

Photochemical reaction chemical reaction influenced or initiated by light, particularly ultraviolet light.

Photochemical smog see smog.

Primary pollutant contaminant emitted directly to the atmosphere.

Pollution rose a pollution rose is produced using wind direction and pollutant concentration data for each hour. The length of each barb segment is proportional to the number of times that the indicated pollutant concentration was measured with the particular wind direction indicated.

Respirable particles particles smaller than about 2.5 microns in diameter, which arise mainly from condensation of hot vapours and chemically driven gas to particle conversion processes; also referred to as $PM_{2.5}$. These are fine enough to penetrate deeply into the lungs and have the greatest effects on health.

Secondary pollutant contaminant formed from other pollutants in the atmosphere.

Smog a contraction of smoke and fog; colloquial term used for photochemical fog, which includes ozone and other contaminants; tends to be a brownish haze.

Smog advisory public is advised when elevated pollution levels are forecast due to ground-level ozone.

Stratosphere atmosphere 10 to 40 kilometres above the earth's surface.

Stratospheric ozone ozone formed in the stratosphere from the conversion of oxygen molecules by solar radiation; ozone found there absorbs much ultraviolet radiation and prevents it from reaching the earth.

Suspended particles suspended particulate matter most likely to reach the lungs (diameter less than 5-10 microns).

Total suspended particulate matter generic term for airborne particles including smoke, fumes, dust, fly ash and pollen; approximately 0.1 to 100 microns in diameter.

Toxic deposition absorption or adsorption of a toxic pollutant at ground, vegetative or surface levels.

Toxic pollutant substance that can cause cancer, genetic mutations, organ damage, changes to the nervous system, or even physiological harm as a result of prolonged exposure, even to relatively small amounts.

Troposphere atmospheric layer extending about 10 kilometres above the earth's surface.

Abbreviations

AAQC	Ambient Air Quality Criteria (Ontario)
API	Air Pollution Index
AQI	Air Quality Index
AQUIS	Air Quality Information System
CO	carbon monoxide
CO_2	carbon dioxide
COH	coefficient of haze reported as SP
CWS	Canada-Wide Standard
EC	Environment Canada
EMRB	Environmental Monitoring and Reporting Branch
EST	Eastern Standard Time
H_2S	hydrogen sulphide
INS	insufficient data to calculate statistic
IP	inhalable particles
LIMA	Lambton Industry Meteorological Alert
MOE	Ministry of the Environment
NAAQS	National Ambient Air Quality Standard (U.S.)
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
O_3	ozone
$PM_{2.5}$	particles less than 2.5 microns
PM_{10}	particles less than 10 microns
RP	respirable particles
SO_2	sulphur dioxide
SO_X	sulphur oxides
SP	suspended particles
TEOM	Tapered Element Oscillating Microbalance
TRS	total reduced sulphur
TSP	total suspended particles
US EPA	United States Environmental Protection Agency
VOCs	volatile organic compounds
kg	kilogram
kPa	kilopascal
kt	kilotonne
$\mu g/m^3$	micrograms (of contaminant) per cubic metre (of air)
ppb	parts (of contaminant) per billion (parts of air)
ppm	parts (of contaminant) per million (parts of air)

References

1. Brook, J.R., Dann,T. and Burnett, R.T., 1997: *The Relationship Among TSP, PM_{10}, $PM_{2.5}$ and Inorganic Constituents of Atmospheric Particulate Matter at Multiple Canadian Locations*. Journal of Air and Waste Management Association, Vol 46, pp. 2-18.

2. Burnett, R.T., Dales, R.E., Krewski, D., Vincent, R., Dann, T., and Brook, J.R., 1995: *Associations Between Ambient Particulate Sulphate and Admissions to Ontario Hospitals for Cardiac and Respiratory Diseases*. American Journal of Epidemiology, Vol 142, pp. 15-22.

3. Environment Ontario, 2001. *Air Quality in Ontario 1998 - A Concise Report on the State of Air Quality in the Province of Ontario.*

4. Environment Ontario, 2001. *Air Quality in Ontario 1998 - Appendix.*

5. Fraser, D., Yap, D., Kiely, P. and Mignacca, D. 1991. *Analysis of Persistent Ozone Episodes in Southern Ontario 1980-1991*. Technology Transfer Conference, Toronto, 1991. Proceedings AP14, pp. 222-227.

6. Fraser, D., Yap, D., Kiely, P., De Brou, G., and Dong, W. 1997. *Daily and Continuous Monitoring of PM_{10} /$PM_{2.5}$ in Ontario*. Presented at the 90th Air and Waste Management Association, Toronto, Ontario, June 1997.

7. Fraser, D., Yap, D., Fudge, D., Misra, P.K. and Kiely, P. 1995. *A Preliminary Analysis of Recent Trends in Ground-Level Ozone Concentrations in Southern Ontario*. Presented at the 88th Air and Waste Management Association, San Antonio, Texas, June 1995.

8. Kiely, P., Yap, D., De Brou, G.B., Fraser, D. and Dong, W. 1997. *A Comparative Study of Toronto's Air Quality and Selected World Cities*. Presented at the 90th Air and Waste Management Association, Toronto, Ontario, June 1997.

9. Lin, C.C.-Y., Jacob, D.J., Munger, J.W., and Fiore, A.M. 2000. *Increasing Background Ozone in Surface Air Over the United States*. Geophysical Research Letters, Vol. 27 (21), pp. 3465-3468.

10. Lioy, P. et al., 1991. *Assessing Human Exposure to Airborne Pollutants*. Environmental Science and Technology, Vol. 25, pp. 1360.

11. Lipfert, F.W. and Hammerstrom, T. 1992. *Temporal Patterns in Air Pollution and Hospital Admissions*. Environmental Research, Vol. 59, pp. 374-399.

12. Lippmann, M. 1991. *Health Effects of Tropospheric Ozone*. Environmental Science and Technology, Vol. 25, No. 12, pp. 1954-1962.

13. Pengelly, L.D., Silverman, F. and Goldsmith, C.H. 1992. *Health Effects of Air Pollution Assessed Using Ontario Health Survey Data*. Urban Air Group, McMaster University.

14. *Rethinking the Ozone Problem in Urban and Regional Air Pollution*. National Academy Press, Washington, D.C., 1991.

15. United States Environmental Protection Agency, *National Air Quality and Emission Trends*, 1998.

16. Wolff, G.T., Kelley, N.A. and Ferman, M.A., 1982. *Source Regions of Summertime Ozone and Haze Episodes in the Eastern U.S.* Water, Air and Soil Pollution, 18: pp. 65-81.

17. Yap, D., Fraser , D., Kiely, P., De Brou, G. and Dong, W. 1997. *The Role of Trans-boundary Flow on 1995 Ozone Levels in Ontario.* Presented at the 90th Air and Waste Management Association, Toronto, Ontario, June 1997.

18. Yap, D., Ning, D.T. and Dong, W., 1988. *An Assessment of Source Contribution to the Ozone Concentrations in Southern Ontario.* Atmospheric Environment, Vol. 22, No. 6, pp. 1161-1168.

19. Yap, D., Fraser, D., Kiely, P. and De Brou, G. 1998. *Preliminary Data Analysis of Real-Time and Daily $PM_{10}/PM_{2.5}$ Monitoring Networks in Ontario.* AWMA paper, 91st Annual Meeting, San Diego, June 1998.

20. U.S. Environmental Protection Agency, AirsData: Air Pollution Monitors, www.epa.gov/airsdata/monreps.htm.

21. Written communication from T. Dann, Environmental Protection Service, Environment Canada, Ottawa, Canada, 1999.

22. Written communication from J. Shelton, NAPS Data, Environmental Technology Centre, Environment Canada, Ottawa, Canada, 1999.

23. Written communication from Air Quality Surveillance Branch, Lawrence, Massachusetts, 1999.

24. Written communication from Air Quality and Source Control Department, Greater Vancouver Regional District (GVRD), 1999.

25. Written communication from South Coast Air Management District, Diamond Bar, California, 1999.

26. Written communication from Minnesota Pollution Control Agency, St. Paul, Minnesota, 1999.

27. Written communication from New York State Department of Environment, Albany, New York, 1999.

28. Written communication from G. Engler, DH10 Environmental Protection Agency, Columbus, Ohio, 1998.

29. Written communication from Quebec Environment, Quebec City, 1999.

30. Written communication from EPA New South Wales, Australia, 1999.

31. Written communication from Air Pollution Control Division, Switzerland, 1999.

32. Written communication from Ambient Monitoring Section, State of Florida, 1999.

33. Written communication from Hong Kong Government, Environmental Protection Department, 1999.

34. Written communication from Helsinki Metropolitan Area Council, Environmental Office, Finland, 1999.

35. Written communication from Department of Natural Resources, Lansing, Michigan, 1999.

36. Written communication from Nova Scotia Department of Environment, Halifax, Nova Scotia, 1999.

37. Written communication from Illinois EPA, Springfield, Illinois, 1999.

38. Written communication from Ministry of Environment, Singapore, 1999.

39. Written communication from Escola Técnica de Saneamento, Brazil, 1999.

40. Written communication from WHO, Geneva, Switzerland, 1999.

41. Written communication from U.O. Fisica & Tutela Dell Ambiente, Milan, Italy, 1999.

42. Written communication from Air Quality Information System, Czech Republic, 1999.

43. Written communication from Berlin, Germany, 1999.

44. Written communication from the Directorate of Air and Noise Control, Athens, Greece, 1999.

45. Written communication from Department of Environment, Fredericton, New Brunswick, 1999.

46. Written communication from Air Issues and Monitoring Branch, Edmonton, Alberta, 1999.

Ministry of the Environment

Printed on recycled paper

PIBS: ~~4143~~ 4159e.
ISBN: 0-7794-2306-2

01-539 09-01